Taeniasis, Cysticercosis and Coenurosis

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Importance

Taeniasis, cysticercosis and coenurosis are parasitic diseases of mammals caused by tapeworms in the genera *Taenia*, *Versteria* and *Hydatigera*. These organisms live in the intestines of the definitive hosts as adults (taeniasis), and in various internal organs of intermediate hosts as bladder-like larvae (cysticercosis and coenurosis). Some taeniids circulate in domestic animals and/or humans; others occur in wildlife cycles or have both domestic and sylvatic cycles. Adult tapeworms tend to cause few or no clinical signs, and serious complications are very rare. Larvae are often carried subclinically as well, but may become symptomatic, especially when they die. The most serious cases are usually associated with larvae in the central nervous system (CNS) or eye, though other tissues and organs can also be affected. Organisms that are infrequently associated with illnesses (e.g., *Taenia saginata*, *T. ovis*) can cause economic losses when they are found in the muscles (meat) during meat inspection.

Humans carry three tapeworms - *Taenia solium*, *T. saginata* and *T. asiatica* - as definitive hosts, with pigs or cattle acting as their major intermediate hosts. *T. solium* is a particular concern because humans can also be intermediate hosts for this organism, and eggs shed by a tapeworm carrier can cause cysticercosis in people, including the carrier. Canids, felids, mustelids and other mammals that eat animal tissues are the definitive hosts for other tapeworms, whose eggs can cause cysticercosis or coenurosis in livestock, pets and various captive or free-living wildlife. Some of these organisms, including parasites from wildlife cycles, have been increasingly recognized in humans in recent years.

Etiology

Taeniasis, cysticercosis and coenurosis are caused by parasites in the genera *Taenia*, *Versteria* and *Hydatigera*, which belong to the family Taeniidae, subclass Cestoda. Infection with the tapeworm stage is called taeniasis, while infection with the larvae is known as cysticercosis or coenurosis, depending on the larval structure. When tapeworm larvae were first found in the internal organs of animals, they were thought to be different parasites and given names in the genera *Cysticercus*, *Strobilocercus* or *Coenurus*. The larval stage of an organism is sometimes still described with the latter name.

There are currently about 45-50 species in the genus *Taenia.* A few taeniids were recently transferred to the genera *Versteria* and *Hydatigera*. Some organisms reported in humans and/or domestic animals include *T. solium* (larval form *Cysticercus cellulosae), T. saginata (Cysticercus bovis), T. asiatica (Cysticercus viscerotropica), T. ovis/ T. ovis ovis (Cysticercus ovis), T. krabbei/ T. ovis krabbei (Cysticercus tarandi), Hydatigera taeniaeformis* (formerly *T. taeniaeformis;* larvae *Cysticercus fasciolaris* or *Strobilocercus fasciolaris) T. hydatigena (Cysticercus tenuicollis), T. multiceps (Coenurus cerebralis), T. serialis* (*Coenurus serialis*), *T. brauni/ T. serialis brauni* (*Coenurus brauni), T. glomeratus/ T. serialis glomeratus, T. pisiformis (Cysticercus pisiformis), T. crassiceps (Cysticercus longicollis), T. martis* and *Versteria mustelae* (formerly *T. mustelae). T. solium, T. saginata* and *T. asiatica* are sometimes called the pig tapeworm, beef tapeworm and Asian tapeworm, respectively. Additional parasites might also be found occasionally in people or domestic animals.

Tapeworms have traditionally been classified into species based on the parasite's morphology, but genetic techniques are increasingly used. The taxonomy of some organisms is still debated. It is uncertain whether *T. brauni* and *T. glomeratus* should be considered species or reclassified as subspecies of *T. serialis*. Likewise, some authors list *T. ovis* and *T. krabbei*, which are morphologically identical, as separate species, but others consider them subspecies of *T. ovis. T. gaigeri* (or *T. multiceps* subsp. *gaigeri)* and *T. skrjabini* are now known to be *T. multiceps.*

Species Affected

The parasites that cause taeniasis, cysticercosis and coenurosis cycle between one or more definitive and intermediate hosts, typically in a predator/ prey or scavenger/prey cycle. They are normally found in mammals and marsupials, but there are rare reports of larvae in birds and snakes.

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Each organism can only develop to mature tapeworms or infectious cysticerci/ coenuri in certain host species, though they sometimes persist and develop for a short time in other animals. Carnivores, especially canids, felids, mustelids and hyaenids, usually act as definitive hosts, while most intermediate hosts are herbivores. However, this is not absolute. Some tapeworms can mature in omnivores such as bears, raccoons, badgers or primates, and carnivores that have ingested tapeworm eggs occasionally become intermediate hosts.

Taenia saginata, T. solium and T. asiatica (cysticercosis)

Humans are the definitive hosts for *T. saginata*, *T. solium* and *T. asiatica*. A few attempts to infect nonhuman primates with *T. saginata* were unsuccessful, but *T. solium* was able to mature in lar gibbons (*Hylobates lar*). This organism also developed into tapeworms in chacma baboons (*Papio ursinus*), though the study ended before the tapeworms produced eggs.

Suids are the usual intermediate hosts for *T. solium* and *T. asiatica.* Wild boar can be infected, but domestic pigs are more important due to their close association with humans. Cysticercosis from *T. solium* has also been seen in other species including sheep, Bactrian camels, deer, dogs, red foxes (*Vulpes vulpes*), felids including domestic cats, lagomorphs (e.g., *Lepus timidus*; *Oryctolagus cuniculus*) and a Cape fur sea (*Arctocephalus pusillu*s). As of 2020, *T. asiatica* has not been reported in naturally infected hosts other than suids, but cattle, goats and some nonhuman primates were infected experimentally.

Cattle, water buffalo and reindeer (*Rangifer tarandus*) are important intermediate hosts for *T. saginata*. Other susceptible animals include llamas, various free-living or captive cervids, and diverse other wild ungulates such as giraffes, various antelopes and gazelles. Wild ungulates generally do not have any significant role in maintaining *T. saginata*.

Taenia crassiceps (cysticercosis)

Various species of foxes, including the red fox (*Vulpes vulpes*), are the most important definitive hosts for *T. crassiceps*. This organism also occurs in wolves (*Canis lupus*), golden jackals (*C. aureus*), raccoon dogs (*Nyctereutes procyonoides*) and other canids, as well as raccoons (*Procyon lotor*) and mustelids. It has been seen occasionally in wild felids such as European wildcats (*Felis silvestris)* or lynx (*F. lynx*). Domestic dogs and cats can be infected, though this seems to be infrequent.

Wild rodents are the usual intermediate hosts, but *T. crassiceps* has been found in lagomorphs, and there are sporadic reports in diverse other species including pet chinchillas (*Chinchilla lanigera*, *Ch. chinchilla*), cats, dogs, foxes, non-human primates and a captive Cape fur seal.

Taenia hydatigena (cysticercosis)

The definitive hosts for *T. hydatigena* include dogs, wolves, coyotes (*Canis latrans*) and other canids. It has been reported occasionally in wild felids including cougars (*Puma concolor)* and lynx, and rarely in domestic cats. There is one report of tapeworms in a grizzly bear (*Ursus arctos*).

T. hydatigena can infect diverse intermediate hosts including sheep, goats, cattle, pigs, wild boar, reindeer, other cervids, several antelopes in the genus *Oryx*, nonhuman primates, stone marten (*Martes foina*), Eurasian beaver (*Castor fiber*), black bears (*Ursus americanus*), rabbits, rodents and other species.

Taenia ovis and Taenia krabbei (cysticercosis)

Dogs and wild canids can both act as definitive hosts for *T. ovis* and *T. krabbei.* However, *T. ovis* mainly infects dogs, while *T. krabbei* usually occurs in wild hosts such as wolves, Arctic foxes *(Alopex lagopus*) and coyotes. *T. ovis* can infect cats, but this seems to be rare, and *T. krabbei* has been seen in bears (*Ursus americanus*, *U. arctos*) and cougars.

Sheep and goats are the usual intermediate hosts for *T. ovis*, while *T. krabbei* is mainly a wildlife parasite in cervids and other ungulates including muskoxen (*Ovibos moschatus*) and mouflon (*Ovis aries musimon*).

Taenia pisiformis (cysticercosis)

T. pisiformis primarily occurs in domestic cycles but can also be established in wildlife. Dogs, wolves, golden jackals, coyotes, and other canids are its definitive hosts. It is most common in farm dogs and other canids that eat lagomorphs. Infections in felids are possible but uncommon.

The intermediate hosts are lagomorphs and, to a lesser extent, rodents.

Taenia martis and Versteria mustelae (cysticercosis)

V. mustelae and *T. martis* use various mustelids (e.g., weasels, ermine, mink, martens, ferrets, badgers) as definitive hosts. *T. martis* has occasionally been reported in non-mustelid hosts such as canids and wild felids (European wildcat), though these reports are uncommon and have been questioned.

Rodents are the usual intermediate hosts for both organisms, which have also been reported in captive nonhuman primates.

Hydatigera taeniaeformis (cysticercosis)

H. taeniaeformis generally uses cats and other felids (e.g., lynx, European wildcats, tigers, bobcats [*Felis rufus*]) as definitive hosts, though it can be found in some dogs, and rarely in foxes and mustelids.

Wild rodents are the usual intermediate hosts. There are occasional reports of *H. taeniaeformis* in birds including Eurasian eagle-owl (*Bubo bubo*) and pheasants (*Phasianus colchicus*).

Taenia multiceps (coenurosis)

T. multiceps occurs in two cycles, one mainly involving dogs and livestock, and the other in various wild canids (e.g., red foxes, Arctic foxes, wolves, hyenas, golden jackals, coyotes and raccoon dogs) and wild herbivores. There are rare reports of *T. multiceps* in felids such as cougars.

Sheep and goats are important intermediate hosts in the domestic cycle. Some other species known to be susceptible include cattle, yaks, horses, dromedary camels, pigs, chamois (*Rupicapra rupicapra*), deer, antelope, other wild ungulates, non-human primates and lagomorphs.

Taenia serialis, T. brauni and T. glomeratus (coenurosis)

Definitive hosts for *T. serialis* can include foxes, wolves, hyenas, coyotes, jackals, and infrequently dogs and cats. Canids are the definitive hosts for *T. brauni* and *T. glomeratus. T. brauni* has also been found in genets.

Lagomorphs are the usual intermediate hosts for *T. serialis*, but it also infects rodents, and it has been reported in other species including cats, a ring-tailed possum (*Pseudocheirus peregrinus*), a grey kangaroo (*Macropus fulginosus*) and nonhuman primates including wild geladas (*Theropithecus gelada*). *T. brauni* and *T. glomeratus* were found in wild rodents. *T. brauni* has also been detected in nonhuman primates

Zoonotic Potential

Only a limited number of taeniids are known to infect people, though some organisms might be missed. Humans are the definitive hosts for *T. saginata* and *T. asiatica*, and can be both definitive and intermediate hosts for *T. solium.* The larvae of *T. crassiceps*, *T. multiceps*, *H. taeniaeformis*, *T. serialis*, *T. brauni*, , *T. martis* and *V. mustelae* have also been found occasionally in people. There is one report of *T. ovis* in the CNS (spinal cord) of a person in the Soviet Union, a single report of *T. hydatigena* in the liver, and one report of *T. glomeratus* from a person in Africa.

Geographic Distribution

T. solium, T. saginata, H. taeniaeformis, T. hydatigena, T. ovis and *T. pisiformis* are cosmopolitan parasites, though control programs, improved sanitation and other factors have made them uncommon in some regions. *T. solium* is most prevalent in parts of Latin America, Asia and subSaharan Africa. Its pig/ human cycle is now absent or mostly absent in many developed countries, though occasional cases of cysticercosis occur in and around human tapeworm carriers. *T multiceps* has been documented in scattered foci throughout the world, including the Americas and parts of Europe and Africa. It appears to be more common in temperate regions. Some countries (e.g., the U.S., Australia, New Zealand) report that this organism is no longer found in domestic animals. *T. serialis* has been reported from North America, Europe, Africa, Australia and some Asian and Middle Eastern countries.

T. asiatica has been documented in a number of Asian countries. One study raised the possibility that it might also exist in Africa, when "*T. saginata*" eggs recovered from two people infected in Ethiopia or Madagascar behaved like *T. asiatica* rather than *T. saginata* in experimentally infected animals. *T. crassiceps, T. krabbei, T. martis* and *V. mustelae* occur in northern temperate zones (e.g., Canada, the northern U.S. and parts of Europe and Asia). To date, *T brauni* and *T. glomeratus* have only been seen in Africa.

Transmission and Life Cycle

Taeniid 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 cysts, which are called cysticerci or coenuri, in various tissues of the intermediate host. The definitive and intermediate hosts for each parasite are usually different species. However, people who carry *T. solium* tapeworms in the intestine can infect themselves or other humans with eggs, resulting in cysticercosis. Autoinfection might also account for cases of *T. crassiceps* cysticercosis in foxes, dogs and cats, though other explanations are possible.

Definitive Hosts - Taeniasis

A definitive host becomes infected when it eats infectious cysticerci or coenuri in raw or undercooked tissues from an intermediate host.

The larvae develop into adult tapeworms, which consist of a scolex attached to the intestinal wall, followed by the parasite's neck and a series of flattened immature, mature and gravid proglottids (segments). Gravid proglottids containing eggs detach from the worm and are shed in the feces. The proglottids of some species, such as *T. saginata* and *T. asiatica*, can also crawl through the anal sphincter to the environment or move away from the feces and attach to vegetation. Other organisms, such as *T. solium*, have non-motile proglottids. Most species have a prepatent period of about 1-3 months. Mature worms can live for several years, and there are reports of some human tapeworms surviving for decades.

Taeniid eggs are infectious immediately. They are relatively sticky, and can adhere to the hands and various fomites. They survive best in cool, humid environments. Eggs have been reported to persist for several months to a year under some conditions, and occasionally longer when protected from sunlight (e.g., 18 months in a cattle barn), but they can be destroyed within a few days if they are exposed to sunlight on the soil surface in a warm environment.

Intermediate hosts – Cysticercosis and Coenurosis

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

migrate to their final location, where they develop into cysticerci or coenuri. Although taeniid eggs are thought to hatch only after they have been exposed to the conditions in the gastrointestinal tract, *T. crassiceps* masses at sites of trauma suggest the possibility of direct inoculation. Development to the mature, infectious cysticercus or coenurus usually takes several weeks or more.

The larval form of *T. solium*, *T. saginata*, *T. asiatica*, *T. crassiceps*, *T. ovis*, *T. krabbei*, *H. taeniaeformis*, *T. pisiformis*, *T. hydatigena*, *V. mustelae* and *T. martis* is called a cysticercus. Cysticerci are fluid-filled vesicles that contain a single inverted protoscolex. A host may have one to hundreds of these cysts. They range from a few millimeters in diameter to about 1 cm (and occasionally larger), depending on the species of parasite and its location. In most cases, each larva develops into a single cysticercus; however, *T. crassiceps* proliferates within the host, with new cysticerci budding off to form masses of cysts, and individual cysts sometimes spreading to other parts of the body.

A coenurus, the larval form of *T. multiceps*, *T. serialis*, *T. brauni* and *T. glomeratus*, is also a fluid-filled vesicle, but it contains multiple protoscolices and is usually a little larger. *T. multiceps* coenuri are about 2-6 cm in diameter, and *T. serialis* up to 5 cm. Each protoscolex can mature into a tapeworm if it is eaten by the definitive host. Daughter cysts may be seen inside some coenuri, either floating freely or attached by a stalk.

While cysticerci and coenuri may be found almost anywhere in the body, each organism tends to develop in certain tissues. *T. saginata* and *T. solium* tend to occur in the muscles of cattle or pigs, respectively, and people often acquire these parasites by eating undercooked beef or pork. *T. asiatica* is particularly common in the liver, and human cases are usually associated with eating undercooked viscera. However, site preferences are not absolute. For instance, *T. solium* has occasionally been found in viscera, and *T. asiatica* in muscle.

Cysticerci and coenuri do not usually cause any inflammatory reaction until they die and degenerate, which may take a few weeks to years. Clinical cases often occur at this time. Degenerating cysts induce granulomatous reactions, which can either be cleared completely or form a calcified scar. Cysts can become noninfectious before they die, while remaining intact and apparently viable.

Ordinarily, cysticerci and coenuri do not pass from one intermediate host to another. However, *T. crassiceps* cysticerci eaten by mice (e.g., during cannibalism) can cross the intestinal wall and become established in the peritoneal cavity of another mouse. The possibility that rare infections might cross the placenta to the fetus was raised when a *T. hydatigena* cysticercus was found in the allantoic cavity of a pregnant goat.

Disinfection

Heat treatment of 60ºC (140ºF) for 5 minutes can inactivate taeniid eggs. The eggs are resistant to chemical disinfectants, and reliable killing requires long exposure times and high concentrations. 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. Prolonged exposure to various hypochlorites or some copper-based compounds can eventually dissolve taeniid eggs. Sodium hypochlorite works most quickly when it is strongly alkaline; more neutral solutions are slower. A preliminary study found that 1.6 mg/ml bunamidine hydrochloride for 1 hour was also promising. Treatment of taeniid eggs for one hour with anhydrous methanol, ethanol, acetone, n-butanol or t-butanol can destroy the eggs, but the addition of water (e.g., 90-95% ethanol) renders these agents ineffective.

Cysticerci in meat can be killed by cooking it to 60°C throughout. Freezing, e.g., at less than -10°C (14ºF) for more than 10-14 days, or less than -7°C (19ºF) for 21 days, is also effective. Current guidelines should be consulted for specific recommendations.

Infections in Animals

Incubation Period

The incubation period for cysticercosis or coenurosis is often months to years. Neurological signs caused by *T. multiceps* coenuri in sheep typically appear in about 2-6 months. Migrating, immature larvae can cause signs much sooner. Young lambs can become ill from migrating larvae 10 days after they ingest *T. multiceps* eggs.

Clinical Signs

Taeniasis

Except for the passage of proglottids, clinical signs are uncommon in the definitive host, and are usually limited to unthriftiness, malaise, decreased appetite, mild diarrhea or colic, and possibly weight loss. Serious complications such as intestinal obstruction, perforation or intussusception are unusual.

Cysticercosis and coenurosis

The type and severity of the clinical signs is influenced by the number and location of the parasites. Many organisms, including some in the CNS, are carried subclinically and only observed as incidental findings at necropsy. Clinical signs mainly result from inflammation associated with degenerating cysticerci and coenuri or the mechanical effects of the parasites, though large numbers of migrating, immature larvae can occasionally cause illness.

T. multiceps causes a neurological condition called gid, staggers or sturdy in sheep and goats. Acute signs from immature, migrating *T. multiceps* larvae are seen mainly in young lambs, though they may also occur in older sheep introduced to a heavily contaminated pasture. Many animals

have only a transient fever, listlessness and mild neurological signs such as a slight head tilt; however, large numbers of parasites can cause acute meningoencephalitis and may be fatal. Migrating larvae of other organisms have been reported to affect tissues outside the CNS. *T. hydatigena* caused an outbreak in lambs with elevated mortality and damage to the liver. It also affected the liver and/or lungs in a few other reports. Large numbers of migrating *T. saginata* larvae caused fever, weakness, anorexia and muscle stiffness in some experimentally infected cattle.

CNS signs from established cysticerci or coenuri develop gradually, and often sporadically, in older animals. Most animals have focal signs related to the location of the cyst(s), but multifocal signs are possible, especially when cysts in the cerebrospinal fluid (CSF) block its flow and cause elevated intracerebral pressure. *T. multiceps* coenuri in sheep have been associated with behavioral abnormalities, circling, head pressing, ataxia, hypermetria, blindness, deviation of the head, paralysis, convulsions and hyperexcitability, as well as prostration and emaciation. Increased intracranial pressure may result in softening of the frontal bone. *T. saginata* does not usually cause CNS signs in cattle, but it sometimes affects reindeer. There are also sporadic reports of CNS signs caused by other organisms (e.g., *T. multiceps*, *T. solium*, *T. serialis*, *T. crassiceps*, *T. brauni*) in various hosts. *T. solium* is thought to be asymptomatic in most pigs, though there are reports of neurological signs (seizures, paralysis of the tongue, hypersensitivity of the snout). A recent report found that this organism might cause subtle behavioral changes or periodic neurological episodes in a significant number of pigs in some endemic areas.

Cysticerci or coenuri found at various sites in the eye, including the retina, can result in visual impairment or blindness. Extraocular cysts in the orbital muscles, eyelid or lacrimal gland may cause exophthalmos, pain and erythema, proptosis or ptosis, and may restrict eye movements. In some regions, nodules caused by *T. solium* are fairly common in the eyelids of pigs.

Cysts in the peritoneal or pleural cavities, liver, lung or other internal organs can sometimes cause clinical signs related to the affected organ, such as abdominal distension, lethargy, weight loss and dyspnea, and may be life-threatening. Some taeniids have caused myocarditis in experimentally infected animals. Cysticerci and coenuri in the muscles and subcutaneous tissues are often well tolerated, with few or no signs, though large numbers of organisms can cause myositis, and cysts in subcutaneous tissues may be visible as nodules or masses. *T. crassiceps*, which can proliferate and metastasize to other sites, usually develops in the subcutaneous tissues or pleural and peritoneal cavities of its rodent hosts. Affected rodents can have massive numbers of cysts and often die within months. *T. crassiceps* has also affected other animals, with cysts reported in body cavities, subcutaneous tissues, the CNS, lung and other sites. Some cases were fatal.

Post Mortem Lesions

Taeniasis

Adult tapeworms may be found in the intestines at necropsy, usually as an incidental finding. They are flat, segmented worms and can be up to several meters long. In rare cases, they may be associated with lesions such as obstruction of the intestinal tract or intussusception.

Cysticercosis and coenurosis

Immature, migrating parasites can cause tissue damage in various organs. Lambs affected by *T. multiceps* often have reddish, pale yellow or gray purulent tracks in the brain, and may also have signs of meningoencephalitis. Similarly, the livers of lambs affected by *T. hydatigena* had hemorrhagic tracks that became greenish-brown with inflammation, and eventually fibrotic. This organism is also reported to cause fibrous adhesions and localized hepatic peritonitis in heavily infected hosts.

Live cysticerci appear as one to hundreds of translucent, whitish, round to ovoid, fluid-filled vesicles in various tissues. With some exceptions (e.g., in the eye or CSF), they are usually surrounded by a fibrous capsule. The protoscolex appears as a dense white body within the cyst. Most cysticerci range in size from several millimeters in diameter (e.g., *T. taeniaeformis*) to about 1 cm, but they can grow larger at some sites, such as the subarachnoid space of the brain. Coenuri are usually somewhat larger; *T. multiceps* and *T. serialis* coenuri can be up to 5-6 cm in diameter. Racemose cysticercosis, which is thought to be caused by abnormal proliferation of *T. solium*, is a grape-like structure containing several connected bladders of various sizes, found at the base of the brain. Its protoscolex, if any, is usually dead. *T. crassiceps* can form masses of attached and/ or individual cysticerci.

While cysticerci and coenuri can be found almost anywhere, each species tends to occur in certain tissues. *T. solium* cysticerci are usually seen in skeletal or cardiac muscles and the CNS, but they occasionally develop in other internal organs such as the liver, lungs, spleen or kidneys. They are relatively common in the eyelid, and are sometimes found in the tongue. *T. saginata* in cattle and *T. ovis* in small ruminants also develop most often in skeletal muscles and heart, while *T. asiatica* in pigs, and *H. taeniaeformis* and *V. mustelae* in rodents, are most common in the liver. *T. hydatigena*, *T. pisiformis*, *T. martis* and *T. crassiceps* tend to develop in the body cavities of their usual intermediate hosts. Some of these organisms may affect visceral organs and *T. crassiceps* is also common in subcutaneous tissues. *T. multiceps* coenuri have been seen in skeletal muscle, myocardium, subcutaneous tissues, CNS and eye, and occasionally in other viscera in small ruminants, while *T. serialis* coenuri tend to occur in the subcutaneous tissues and muscles of lagomorphs.

Cysticerci and coenuri are usually associated with inflammation only when they are degenerating. As the organism dies, the cyst wall thickens and becomes

increasingly opaque. The fluid inside gradually thickens, and the cyst eventually becomes filled with greenish to yellowish caseous material. Some cysts disappear completely; others leave calcified lesions.

Diagnostic Tests

In the definitive host, taeniasis can be diagnosed by finding proglottids in the feces, on the animal, or in the environment, and taeniid eggs in the feces by fecal flotation, sedimentation or other techniques.

While the proglottids are still moist, their morphology can help identify the organism to the genus level. Injecting the proglottid with India ink can reveal structural details and aids in distinguishing some species. PCR and other genetic techniques can more reliably identify the specific organism, but are rarely used for taeniasis in animals except in research. Repeated sampling may be needed to detect the eggs, as they are shed intermittently, and are not concentrated efficiently by the usual flotation methods. Taeniid eggs are dense and brown, with a striated embryophore coat. Coproantigen assays can detect taeniid antigens in feces, but do not usually distinguish different species.

Diagnosis of cysticercosis or coenurosis can be difficult in live animals. In sheep, *T. multiceps* coenurosis is sometimes suspected if there is refraction upon palpation of the skull behind the horn buds and consistent clinical signs. Imaging studies such as MRI or ultrasound are used occasionally, especially in smaller animals, and biopsies may be helpful if the cyst is accessible. Fine needle aspiration is sometimes but not always diagnostic. Taeniid species have traditionally been identified by their morphology; however, this can sometimes vary between hosts or stages of the organism, and it is less reliable than genetic methods. Some species, such as *T. ovis* and *T. krabbei*, appear identical.

ELISA tests that detect antigens from actively growing larvae are sometimes used in *T. solium* control programs, but they are not sensitive enough for use in individual pigs. Cross-reactions with *T. hydatigena* are possible. Serology is not normally used for diagnosis in animals.

Treatment

Taeniasis is treated with anthelmintic drugs such as praziquantel, niclosamide, epsiprantel, mebendazole, febantel or fenbendazole. Niclosamide is not absorbed from the intestine.

Treatments for cysticercosis or coenurosis may include anthelmintic drugs and/or surgery, though there is less experience in animals than humans. Benzimidazoles (e.g. flubendazole, fenbendazole, albendazole, oxfendazole) and praziquantel can kill the cysts in some locations. Drug treatment can exacerbate the clinical signs when the larvae die, and immunosuppressive drugs are usually administered concurrently, especially in CNS disease. In humans, cysts in the brain parenchyma generally respond better to drug treatment than those in the ventricles/ CSF.

Control

Disease reporting

Veterinarians who suspect an animal is infected by a member of *Taenia*, *Hydatigera* or *Versteria* should follow their national and/or local guidelines for disease reporting. State regulations should be consulted in the U.S.

Prevention

Taeniasis can be prevented in cats, dogs, ferrets and captive carnivores by not allowing them to hunt rodents or other intermediate hosts, and by not feeding them raw or undercooked animal tissues. Controlling cysticercosis and coenurosis depends on reducing an animal's exposure to the eggs. Where feasible, it can be easier to control these illnesses by focusing on the definitive host. Control programs for *T. ovis*, which is an economically important parasite in some sheep-raising areas, have included regular deworming of farm dogs and bans on feeding these dogs tissues from sheep unless the larvae are first destroyed by cooking or freezing. Dead stock should not be left to be eaten by other canids.

T. solium, *T. saginata* and *T. asiatica* eggs are shed by people, and human sanitation is important in controlling these infections in animals. The only formal control programs are for *T. solium* and are intended to reduce cysticercosis in humans. Measures that help eliminate *T. solium* from swine include sanitation projects that reduce pigs' exposure to human feces, treatment of infected people, and confinement of free-roaming pigs. Some trial programs have also treated infected pigs with oxfendazole to eliminate cysticerci and/or used experimental porcine *T. solium* vaccines. One swine vaccine is now commercially available in some countries. It does not destroy existing cysticerci but can help prevent new infections. Vaccines for some other tapeworm larvae (e.g., *T. ovis*, *T. saginata)* also appeared to be effective in clinical trials, but they were not marketed for economic reasons.

Morbidity and Mortality

Taeniasis is usually subclinical or mild, and serious complications are very rare. Cysticercosis and coenurosis are more likely to be symptomatic, though most organisms tend to cause only sporadic clinical cases or outbreaks and infect many animals asymptomatically. Infections are more likely to become apparent when the cysts affect the CNS or eye, or when the parasites occur in unusually large numbers. Clinical cases, especially those affecting vital organs, are sometimes fatal. Some taeniids, such as *T. ovis*, are mainly an economic concern, causing losses when the cysts are found in muscles at meat inspection.

T. solium is usually infrequent or absent in industrialized pig production and developed countries. However, up to 43% of pigs may be seropositive in some endemic areas in Asia, Africa and Latin America. Free-roaming pigs are more likely to be infected than animals confined to a pen. *T. saginata* seems to be less prevalent in cattle, with fewer parasites per

animal, possibly because they tend to avoid grazing in areas with significant human fecal contamination. This organism can infect more than 5% of the cattle in some regions, but its prevalence is often less than 1% in developed countries. Occasional outbreaks have been seen in feedlots, including several incidents in North America linked to infected workers who shed eggs.

Control programs have reduced the incidence of some economically important taeniids. In the 1980s, 0.5-6% of the sheep in the U.K. were infected with *T. multiceps* at slaughter, but this organism became uncommon after control programs were implemented in dogs. Urban fox populations may increase the risk of cysticercosis from *T. crassiceps*. This tapeworm does not seem to be common in cats and dogs: surveys report an incidence of ≤ 1%, with the highest infection rates in stray cats.

Infections in Humans

Incubation Period

As in animals, cysts often become symptomatic only when they are degenerating or become large enough to interfere with vital organs. In most cases, the incubation period is thought to be months to years.

Clinical Signs

Taeniasis

Taeniasis is often asymptomatic except for the passage of proglottids in the stool and, in people infected with *T. saginata*, active migration of proglottids through the anus. Some people also have mild abdominal symptoms, which may be intermittent, and can include abdominal pain, periods of diarrhea or constipation, nausea and decreased or increased appetite. Weight loss is possible but not common. Symptoms occur more often in children than adults, and are typically relieved by eating small amounts of food. Vomiting, diarrhea, fever, weight loss and irritability have been reported in infants. Complications such as intestinal obstruction or perforation have been seen in people, but are very rare.

T. saginata proglottids can occasionally migrate to locations such as the appendix, uterus or bile duct, which may result in appendicitis, cholangitis or other syndromes. There are only rare reports of *T. solium* in aberrant locations, such as a case of cholecystitis caused by a worm that had traveled up the bile duct.

Cysticercosis and coenurosis

As in animals, cysts can be carried with or without clinical signs. The symptoms vary with the location and number of larvae.

Neurocysticercosis, which is caused by *T. solium* and occasionally other parasites (e.g., *T. crassiceps*, *T. martis*), may either develop insidiously or have a sudden onset. Parenchymal neurocysticercosis (cysts in the brain tissue) and extraparenchymal neurocysticercosis (cysts in the ventricles and other sites where CSF circulates) tend to have different clinical signs and prognosis. The most common symptoms in the parenchymal form are chronic headaches, seizures and focal neurological signs related to the location of the cyst. These signs are often intermittent, occurring over days, weeks or months. Some patients may also experience nausea, vomiting, vertigo, ataxia, confusion or other changes in mental status, and behavioral abnormalities or progressive dementia. Complications can include vasculitis, hydrocephalus, intracranial herniation or inflammation of the meninges (meningitis). Left untreated, some parenchymal cysticerci eventually resolve on their own, though this may take months or years. However, they can also be fatal or result in permanent neurological deficits. A minority of patients continue to have seizures after recovery, possibly due to calcified remnants of cysts.

Extraparenchymal neurocysticercosis is more clinically aggressive, as the cysts in CSF continue to grow. The symptoms tend to be a consequence of increased intracranial pressure, can be intermittent, and are sometimes induced by head movements. The clinical course ranges from mild symptoms intermittently for years to life-threatening deterioration over hours. Complications are similar to those in the parenchymal form. Spinal neurocysticercosis, once thought to be rare, is now known to affect a significant number of people with extraparenchymal cysticercosis. The signs can include motor and/or sensory dysfunction and nerve root pain.

Cysticercotic encephalitis is a rare and severe form of neurocysticercosis caused by large numbers of cysts in the brain. The resulting inflammation can cause cerebral edema and an encephalitic syndrome. It is often fatal. Neurocoenurosis (e.g., *T. multiceps, T. serialis)* is similar to neurocysticercosis, but less common and not as well understood. *T. multiceps* coenurosis has often been associated with severe CNS signs, and a significant number of the cases were fatal.

Ocular cysticercosis can affect one or both eyes. The cysts tend to be found in the vitreous humor or subretinal space/ retina, but they can also occur in other parts of the eye, including the anterior chamber, lens, or optic nerve head, as well as under the conjunctiva. Common symptoms include visual disturbances and severe pain. Blindness is possible. Cysts are also found occasionally in extraocular tissues such as the orbital muscles, eyelid or lacrimal gland. Mass effects at these sites, or inflammation from dying parasites, can result in pain and erythema, proptosis or ptosis, and diplopia caused by restrictions on the eye muscles.

Cysts in the muscles are usually asymptomatic, though myositis is possible. Subcutaneous cysticerci and coenuri appear as nodules and masses, which may or may not be painful. The cysts of *T. solium* and most other species usually have a good prognosis when they occur in muscles or subcutaneous tissues; however, *T. crassiceps* can be more serious. This organism can cause large, expanding subcutaneous masses which may disseminate to other sites, including internal organs. Some masses from *T. crassiceps* can

resemble tumors, and one case mimicked necrotizing fasciitis. Superficial nodules caused by *T. solium* or other organisms have also been reported occasionally in the mucosa of the oral cavity, including the tongue and lip. Rarely, cysts can cause vasculitis or obstruct small arteries, leading to a stroke. Cysticerci in the heart are often an incidental finding, though they may result in conduction abnormalities.

Disseminated cysticercosis is an uncommon condition that has been seen in immunocompetent as well as immunocompromised patients. Cases can involve many different organs and tissues such as the muscles, subcutaneous tissues, CNS, and internal organs such as the lung, liver, kidney or spleen. There may be nonspecific signs such as fatigue, malaise and myalgia, as well as signs related to the affected organs (e.g., cough, abdominal pain). Although fever is unusual in most forms of cysticercosis, it has been seen in some patients with disseminated disease.

Diagnostic Tests

Taeniasis

Taeniasis can be diagnosed by demonstrating proglottids or eggs in the feces or other samples, such as adhesive tape preparations taken near the anus. Diagnostic methods (flotation, sedimentation, Kato–Katz tests) and identification techniques are similar to those used in animals. Coproantigen ELISA tests might be available.

In humans, it is particularly important to identify clinical cases caused by *T. solium*. This organism's proglottids can be distinguished from *T. saginata* and *T. asiatica* by their morphology, using India ink preparations. The proglottids of *T. saginata* and *T. asiatica* appear identical. Where they are available, genetic techniques (e.g., PCR, multiplex loop-mediated isothermal amplification tests) can distinguish these three organisms. Some authors have suggested using Ziehl Neelsen staining to distinguish *T. saginata* eggs (acid fast) from those of *T. solium*, but a recent study found it to be unreliable.

Cysticercosis

Neurocysticercosis is usually diagnosed with imaging studies (CT scans or MRI), combined with serology or assays to detect parasite antigens or nucleic acids. Extraparenchymal cysts may be difficult to visualize, as their density is similar to CSF. They are more easily found with specialized MRI techniques. Ultrasound has sometimes been used for cysts in other locations, such as subcutaneous tissues and the eye, while calcified cysts in the muscles and brain may be seen on x-ray. Fine needle aspirates of cyst contents may be helpful in diagnosing subcutaneous nodules and other accessible cysts, though not all aspirates are diagnostic. Immediate examination and re-sampling results in fewer nondiagnostic samples.

Most countries use the enzyme-linked immunoelectrotransfer blot (EITB) assay and/or ELISAs to detect antibodies to *T. solium* in blood or CSF. EITB is more sensitive and specific, but it is not available everywhere. Some infected patients can be seronegative, especially when the number of cysts is low. Conversely, people who have cleared the infection may be seropositive.

Where they are available, ELISAs to detect parasite antigens are generally preferred over serology. They are thought to detect only live larvae. Either serum or CSF can be used; however, serum also detects infections outside the CNS, which may complicate the diagnosis of neurocysticercosis. False negatives are possible, especially when there are only a few cysts in the brain parenchyma. PCR tests may be able to detect nucleic acids in CSF samples, and appear to be particularly useful in extraparenchymal neurocysticercosis.

Coenurosis

Coenurosis is diagnosed similarly; however, these organisms are uncommon in humans and specific serological assays have not been developed.

Treatment

Taeniasis is usually treated with praziquantel or niclosamide, but other anthelmintics (e.g., tribendimidine, buclosamide, albendazole, mebendazole, paromomycin) are also effective. Niclosamide is considered safer in *T. solium*-infected patients who might have concurrent neurocysticercosis, as it is not absorbed from the intestine.

Cysticercosis and coenurosis may be treated with anthelmintic drugs, surgery, or both. Albendazole and praziquantel are the most commonly used drugs, but other drugs such as ivermectin have also been used. Intraocular cysts are usually managed surgically, as dying parasites can cause damaging inflammation inside the eye. The treatment of neurocysticercosis can be influenced by the location, number, size and status (e.g., viability) of the cysts, and recommendations vary. Steroids are given concurrently with anthelmintics, to avoid exacerbating the clinical signs when the parasites die. Some patients also need symptomatic care for seizures or elevated intracranial pressure.

Prevention

Taeniasis can be avoided by not eating raw or undercooked animal tissues, especially pork (*T. solium*), pork liver (*T. asiatica*) and beef (*T. saginata*). Potentially contaminated meat should be cooked to 60-65°C (140-149°F) throughout. Commercial cold or heat treatment protocols or irradiation can destroy the cysts. Meat inspection reduces the risk of infection to some extent, but some cysts can be missed.

Cysticercosis or coenurosis is acquired by ingesting taeniid eggs. Good hygiene including hand washing is helpful, especially when preparing food. In endemic areas, vegetables and fruits should be washed well, and peeled when they will not be cooked. In areas with unsafe water supplies, only bottled water, filtered water, or water that has been boiled for at least one minute should be drunk. Human sewage should not be used to irrigate crops. People carrying *T. solium* tapeworms in the intestines should be treated promptly.

T. solium control programs have been tested in several areas. They typically consist of education combined with control efforts directed at both human tapeworm carriers and pigs (see Control, Animals).

Morbidity and Mortality

T. saginata, *T. solium* and *T. asiatica* infect significant numbers of people in endemic regions. *T. solium* cysticercosis and taeniasis is often clustered in households, due to person-person transmission via eggs shed by a tapeworm carrier. This organism is most prevalent in certain rural areas where sanitation is poor, access to safe water supplies may be limited, and pigs can contact human feces. In these regions, studies have found exposure rates ranging from 13% to more than 50%, and up to 10-20% of asymptomatic people have evidence of live or calcified (dead) cysts in the brain. *T. solium* is uncommon in developed countries with good sanitation and healthcare, but small clusters of cases can be seen periodically, often surrounding a tapeworm carrier who was infected elsewhere.

T. solium is assumed to be responsible for most cases of cysticercosis. Coenurosis seems to be much less common, with less than a few hundred cases reported worldwide to date. Because taeniids are infrequently identified to the species level, the incidence of some organisms might be underestimated. *T. martis* and *V. mustelae* were not known to affect humans until recently, and one study found that, of a small number of clinical cases that could be genetically analyzed, 3 were caused by *T. solium*, one by *T. crassiceps* and one by *T. serialis*.

Many infected people have few or no clinical signs. About 55-65% of human tapeworm carriers are estimated to be asymptomatic, and other cases are usually mild. Larvae, including most cysticerci in the brain, are also frequently subclinical. In clinical cases, the severity of the illness varies with the parasite and the location, number and size of the cysts. *T. crassiceps*, which proliferates and can spread to other sites, is a particularly dangerous organism. While it has been reported more often in those who are immunosuppressed, it also occurs in immunocompetent people. As of 2020, *T. martis* has been seen in a small number of immunocompetent patients and affected only a single site (CNS, eye, abdominal cavity) in each person, while all three *V. mustelae* infections occurred in people who were immunosuppressed, affected multiple internal organs, and caused serious or fatal illnesses.

Parenchymal neurocysticercosis caused by *T. solium* usually has a good prognosis. It may resolve even without treatment, especially in children, who often present with a single degenerating cyst in the brain. Extraparenchymal neurocysticercosis is more likely to be progressive and severe or fatal. The case fatality rate in this condition was 20-50% at one time, though the survival rate has greatly improved during the last 30 years. Cysticercotic encephalitis, which is most common in children and teenagers, is a particularly dangerous disease. Although it is rare, it is often fatal. Cysticercosis has also been suggested to be a major contributor to epilepsy in endemic regions, though this is controversial.

Internet Resources

Centers for Disease Control and Prevention (CDC). Parasites (Cysticercosis, Taeniasis)

eMedicine.com Cysticercosis in Emergency Medicine

FAO Manual on Meat Inspection for Developing Countries

Public Health Agency of Canada. Pathogen Safety Data Sheets

The Merck Manual

The Merck Veterinary Manual

World Health Organization (WHO). Taeniasis/cysticercosis

WHO. *Taenia solium* taeniasis/cysticercosis

World Organization for Animal Health (WOAH)

WOAH Manual of Diagnostic Tests and Vaccines for Terrestrial Animals

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