Taeniosis remains a threat

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Abstract

Taeniosis recorded in the last months belongs to zoonotic diseases. Consumption of raw or undercooked pork and beef has a key role in its development. This article sumarizes main characteristic of tapeworms, their life cycle, survival of cysticerci in cattle and pig tissues and preventive measures which significantly reduce the risk for final consumers.

Taenia saginata, Taenia solium, cysticercus, meat, inspection, prevention

Introduction

In April, the media reported an outbreak of human taeniosis. Several people who confirmed the consumption of raw beef were infected. A brief reminder of the basic facts about tapeworms, their life cycle and preventive measures that are applied during food processing may help reduce the prevalence of the disease and prevent further infections.

The confirmed causative agent in the latest outbreak of human taeniosis in the Opava region was *Taenia saginata* (beef tapeworm). This species of tapeworm, like the other species of tapeworm important for humans, i.e. *Taenia solium* (pork tapeworm), is a tapeworm with an indirect life cycle. *Taenia asiatica* ("Taiwan" *Taenia)* is a newly described tapeworm of the genus *Taenia* that infects humans. Genetic studies have determined that *Taenia asiatica* is closely related to the species *T. saginata*, though its intermediate hosts are domestic pigs. The occurrence of this species has been reported in Taiwan, Korea, Indonesia, Vietnam and China, and is, therefore, of extremely little importance in this country (Eom 2006).

Adult tapeworms live in the small intestine of humans where they grow to several meters in length. Humans usually serve as host to just a single tapeworm which lives for a number of years in their small intestine. The tapeworm's body consists of a scolex with four suckers. *T. solium* is, moreover, armed with hooks and a rostellum. The scolex is followed by a short neck, from which a long chain of proglottids or segments proliferate. The segments contain both male (testes) and female (ovary, branched uterus) reproductive organs. Tapeworms are hermaphrodites which produce eggs that are accumulated in their individual body segments. Mature segments are shed in the faeces. Segments of *T. saginata* are, moreover, capable of actively migrating out of the anus, which is accompanied by itching. Tapeworm eggs are oval in shape and thick-walled. They contain larvae called oncospheres. Their survival in the external environment depends on the temperature and humidity of the substrate. They can survive for up to nine months under favourable conditions, though they will die within days in warm weather and in a dry substrate. The eggs are about 26–34 μm in size. The species of tapeworm is identified on the basis of the morphology of their scolex and segments. The eggs of *T. solium*, *T. saginata* and *T. asiatica* cannot be distinguished morphologically. Basic features that can be used to differentiate between individual tapeworm species are shown in Table 1 (Kyvsgaard and Murrell 2005; OIE 2012).

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Table 1. Important features differentiating species of tapeworms of the genus *Taenia* (Kyvsgaard and Murrell 2005; OIE 2012)

Species	Length/width	Scolex features	No of uterine branches	No of testes	Other features
T. saginata	4–8 m, 12–14 mm	4 suckers, no rostellum or hooks	14–32	765–1.200	well-developed vaginal sphincter
T. solium	2–5 m, 7–10 mm	4 suckers, rostellum and 2 circles of 22–36 hooks	7–16	375–575	no vaginal sphincter

Cysticerci, a developmental stage of tapeworms, usually occur in intermediate hosts which, in the case of *T. saginata*, are cattle, buffalos, reindeers and the cervids. Cysticerci are usually found in muscle tissues, though they may occasionally infest certain organs. Cysticerci of *T. solium* occur in muscle tissues and the central nervous system (CNS) of pigs, bears and dogs, and also in subcutaneous tissues, muscles and CNS in humans. Cysticerci, which grow to around 0.5–1 x 0.5 cm in size, are translucent and contain a scolex with the same structure as in adult individuals. When the human acts as the intermediate host for tapeworms, the disease is called human cysticercosis. The infestation of animals with tapeworm larvae is called bovine or porcine cysticercosis (Cardenas et al. 1992; OIE 2012).

Prevalence and modes of transmission

T. solium

T. solium can be found on pig farms with poor hygiene conditions where pigs come into contact with human faeces. Intermediate hosts (both domestic and wild pigs) become infected by ingesting parasite eggs from which oncospheres hatch in the digestive tract and are carried in the blood to muscle tissues and organs in which they develop into cysticerci (Cysticercus cellulosae). They are present in muscle tissues about 6 weeks post infection. Eggs may cause infection in humans in the same way. Such infections are often caused by autoinfection in people who host an adult tapeworm in their intestine (García et al. 2003). People can become infected by eating raw or undercooked pork meat containing cysticerci. Tapeworm larvae will then envaginate, attach themselves firmly to the mucous membrane of the duodenum or jejunum by means of suckers or hooks, and start producing segments – proglottids. Mature proglottids are excreted in faeces within two months post infection, each segment containing 50–60 x 10^3 eggs (Flisser 1994). The life cycle is shown in Plate V, Figure 1.

T. saginata

T. saginata is a parasite with a cosmopolitan distribution, though it is associated with cattle farming. Cattle, as the intermediate host, become infested by ingesting eggs contaminating feed or water (Geysen et al. 2007). Transmission to muscle tissues is the same as in pigs. *Taenia saginata* cysticerci can be seen with the naked eye between two and four weeks post infection as nodules in striated and cardiac muscles, measuring 2-5 mm in diameter, including the surrounding inflammatory tissue reaction. Cysticerci can be detected macroscopically 8 to 10 weeks following the ingestion of eggs and remain infective for months. They become calcified in the course of time. Cysticerci can be found not just in muscle tissues, but also in the liver, lungs, kidneys and heart. People become

infected by eating raw or undercooked beef containing cysticerci. Tapeworms reach sexual maturity two or three months post infection and mature segments can spontaneously migrate from the host's anus or are excreted with the faeces into the external environment (Allepuz et al. 2009). The life cycle is shown in Plate V, Fig. 2.

Pathogenicity and virulence of the causative agent

Adult tapeworms in human intestines usually cause mild inflammation at the site of attachment without any significant damage to the intestine (Merchant et al. 1998). The presence of a tapeworm in the host is associated with clinical symptoms such as abdominal pain, distension, diarrhoea, nausea and weight loss, though the majority of definitive hosts are usually asymptomatic (Flisser 1994). The main symptom of active migration is pruritus ani; this is a condition more frequent in taeniosis caused by the beef tapeworm than by the pork tapeworm. Diagnosis of human taeniosis is performed by stool examination. Both tapeworm segments and eggs are shed irregularly and stool samples are therefore examined repeatedly. In the case of anal itching in *T. saginata* infections, samples can be taken from perianal region using swabs or adhesive tape. Patients who collect samples themselves need to exercise caution to prevent autoinfection, particulary in *T. solium* infections. Parasitological examination is positive when tapeworm eggs or entire segments are found in the stool. Species identification relies on molecular biology methods (PCR, PCR-RFLP) or on specific detection (ELISA) of the tapeworm coproantigen present in the stool. When they have been removed from the definitive host's intestine, the species of adult tapeworm is determined on the basis of the morphology of the scolex and individual segments (OIE 2012).

The larval stage of tapeworms which migrate outside the intestinal tract in the human organism are the cause of much more serious symptoms. Human cysticercosis has been described only in *T. solium* infection. It causes inflammatory changes in the CNS, intracranial hypertension and hydrocephalus. It often manifests itself in epileptic seizures and can have a fatal outcome (Nash and Teva 1984). Neurocysticercosis occurs several months or even years post infection and the symptoms that manifest themselves are related to the degeneration of cysticerci that elicits a response from the surrounding tissue. Although ocular cysticercosis is rare, *T. solium* is the most frequent intraorbital parasite (Rahalkar et al. 2000). It causes retina damage, chronic uveitis and is associated with vision disorders (Cardenas et al. 1992). Symptoms associated with muscle or subcutaneous tissue infections are more moderate. Subcutaneous cysticercosis manifests itself as small painless nodules in subcutaneous tissues which will spontaneously disappear after several months or years. Another possibility is muscular cysticercosis manifested by calcified nodules in muscles, accompanied on rare occasions by muscular pseudohypertrophy. The diagnosis of human cysticercosis is performed on the basis of a thorough investigation of case history, clinical signs and symptoms, computer tomography and magnetic resonance of the brain and serological detection of specific antibodies in blood serum or cerebrospinal fluid (OIE 2012).

Diagnosis of cysticercosis

Cysticercosis in live animals can only be diagnosed by serological tests. The main diagnostic and preventive step in slaughtered cattle and pigs is veterinary inspection. Not even such inspection, however, results a 100% detection rate, though its sensitivity can be enhanced if performed by experienced veterinary surgeons with a good knowledge of the procedure. It must always be kept in mind that current meat inspection procedures are more effective in detecting heavily infected carcasses than mildly infected carcasses.

During the veterinary examination, attention is focused on the muscle tissue that has a high blood flow and is, therefore, the most vulnerable. Predilection sites for cysticerci include the heart, the tongue, masseter muscles and the diaphragm. Cysticerci are initially invisible because they form small cysts 1 mm in size that can only be demonstrated when tissues are sectioned and examined under the microscope. Cysticerci can appear in tissues as early as two weeks post infection, though they usually become visible only after about six weeks. They are already mature at this time and capable of causing infection, oval in shape and approximately 1 x 0.5 cm in size or larger (Plate VI, Fig. 3). A tapeworm scolex is visible within the fluid-filled cysticerci. A large majority of cysticerci (85–100%) found during veterinary inspections are usually dead. The speed at which cysticerci reach maturity, die and degenerate depends on the type of tapeworm and the organ it is found in. Cysticerci usually die 9 months after infection, though they remain visible in tissues for a number of years. Cysticerci in skeletal muscles die more quickly than those in the myocardium. The appearance of cysts undergoing degeneration changes. The fibrous capsule made up of the host's tissue thickens and becomes opaque. Its fluid content becomes thicker and includes inflammatory infiltrate. Vesicles become larger and the colour and consistency of their content change into a green-yellow caseous substance. Later, cysticerci become calcified. If animals are treated with antiparasitic drugs (Albendazole, Oxfendazole), the cysts lose their fluid content and collapse. The resulting lesions are much smaller than they would have been had degeneration occurred without treatment.

A veterinary inspection aimed at demonstrating the presence of tapeworms in cattle and pigs includes:

1) adspection of the carcass, its surfaces and organs
2) incisions into the external and internal masseter muscles in cattle
- incisions are made parallel to the lower jaw starting from the ventral edge of the mandible and continuing to the temporomandibular joint (Plate VI, Fig. 4)
- two incisions are made into the external masseter muscles and one flat incision into the internal masseter muscles
3) visual inspection of the tongue and palpation of it (applies particularly to *T. solium*)
4) visual inspection of the pericardium and heart
- a single incision is made into the heart cutting through the left atrium and the interatrial septum and making examination of myocardium (Plate VII, Fig. 5)
- the incision is made from the cardiac base toward the apex
5) visual inspection of the diaphragm
6) visual inspection of the oesophagus

No incisions into the masseter muscles need to be made if cattle are delivered to the slaughterhouse accompanied by a certificate of a negative serological test for cysticercosis. The other steps of the described veterinary inspection remain in place. Inspection of cattle aged less than 6 weeks includes merely a visual check of visible organs and tissues. Incisions into the masseter muscles are not obligatory. Myocardium inspection is always required.

If cysticerci are found on organs or in muscles during an examination, it is necessary to determine the extent of the infestation. For this reason, more detailed incisions are made into other parts of the carcass, particularly the muscles of the shoulder, fillet, loin/rib, spare rib/chuck. Cysticerci in pigs are found most frequently in shoulder muscle about 3 cm above the elbow joint.

The entire carcass, including blood and internal organs, is declared unfit for human consumption in the case of a generalised infestation. Infestation is considered generalised if cysticerci are found in at least two sites of predilection and also in shoulder or round muscle tissues. In mild infestations (up to 20 cysticerci in the entire carcass), only the

organs infested and their immediate surroundings are condemned. The remaining tissues can be used for human consumption after proper treatment/processing during which the cysticerci are reliably devitalised. (Regulation (EC) No. 854/2004; Kyvsgaard and Murrell 2005; OIE 2012).

Devitalisation of cysticerci

In the case of live animals, meat can be assured by treating the animals. This approach has been used, to a certain extent, in pigs in areas with a high prevalence of the condition. The treatment consisted of the application of Oxfendazole at a dose of 30 $mg.kg^{-1}$. All cysticerci were reliably destroyed within 8 to 12 weeks of the antiparasitics being administered. This treatment is, however, rather expensive, for which reason preventive measures are preferred.

Cysticerci present in pork or beef can be effectively devitalised by three methods. The first method is thorough heat treatment during which the temperature inside the meat must reach at least 80 °C. An even better approach is to boil the meat for at least 30 minutes. The second type of treatment is freezing the meat. The length of the cold treatment period depends on the temperature. Cold treatment is considered effective if the meat product is frozen to:

1) - 5 °C for 360 hours (15 days)
2) -10 °C for 216 hours (9 days)
3) - 15 °C or a lower temperature for 144 hours (6 days)

The third recognised method that assures devitalisation of cysticerci is salting. Grinding does not guarantee reliable destruction of all the cysticerci present, and this method cannot be considered adequate. Meat subjected to one of the above treatments is not intended for export and is usually consumed within the given country (Kyvsgaard and Murrell 2005; OIE 2012).

Epidemiologic risks, preventive measures

Tapeworm infection can be ranked among the alimentary diseases that are rare among the population of the Czech Republic thanks to thorough preventive measures applied at all steps of meat processing. The number of animals diagnosed with cysticercosis in recent years is given in Table 2.

The majority of carcasses with cysticercosis were released for distribution after being subjected to one of the effective types of treatment. In view of the large number of food animals slaughtered every day, the number of positive cases detected is extremely low and testifies to the effectiveness of preventive measures in place in the primary

Table 2. Detection of cysticercosis at slaughterhouses in the CR in the years 2010–2013 (The State Veterinary Administration of the Czech Republic)

Year	No of positive animals	No of carcasses passed for consumption after treatment
2010	99	93
2011	93	81
2012	70	60
1.01–10.04.13	10	8

production sector. Some experts consider porcine cysticercosis potentially eradicable, while the prevalence of bovine cysticercosis is also on the decline (Kyvsgaard and Murrell 2005).

Epidemiologic risks in regions in which *T. solium* is endemic include inadequate hygiene conditions in households and inadequate personal hygiene habits, subsistence pig production and slaughter, the eating of raw or undercooked pork, a low level of education, and the hosting of adult tapeworms by family or community members (Sciutto et al. 2000). Similar aspects also play a role in the transmission of *T. saginata.*

Eating raw meat, in the form of the popular steak tartare for example, is always at the consumer's own risk. Although all the carcasses that are released for distribution have been examined and inspected by veterinarians, cases of mild cysticercosis infection may be missed. This is corroborated, inter alia, by alerts regarding specific products that are issued from time to time by the Rapid Alert System for Food and Feed (RASSF). The most recent alert was issued in 2009, when the presence of Cysticercus bovis was confirmed in chilled beef distributed to Germany, France and the Netherlands.

Preventive measures must take into account all possible means of transmission, both between intermediate and definitive hosts, and prevent animals themselves from becoming infected by ingesting eggs. The following preventive measures are conducted in practice:

1) prevention of contamination of feed and water for pigs and cattle with human faeces
2) observation of the rules for the use of sludge from waste water treatment plants in agriculture
3) veterinary inspections of meat and organs of food animals
4) educating workers in the entire food production chain
5) thorough cooking of meat

In addition to the effective measures already introduced, awareness among consumers of the risks of infection with these parasites must also be enhanced.

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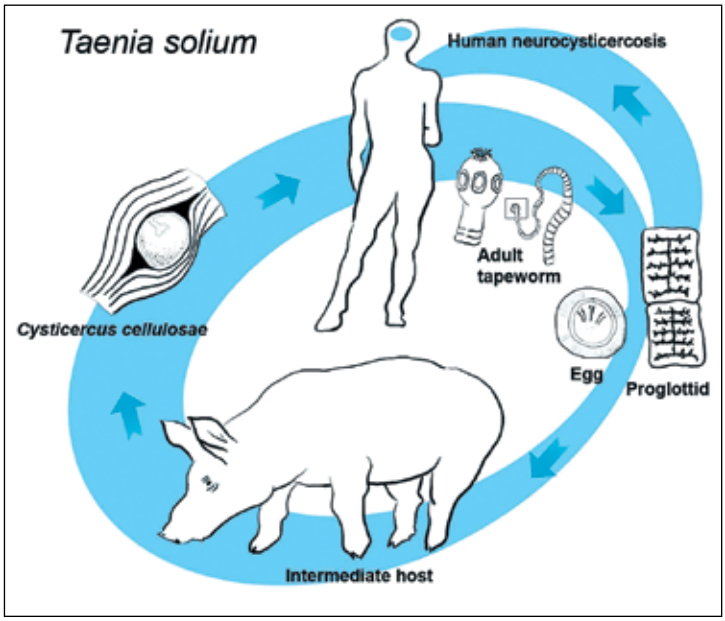

Fig. 1. Life cycle of *T. solium* (Kateřina Špůrková©)

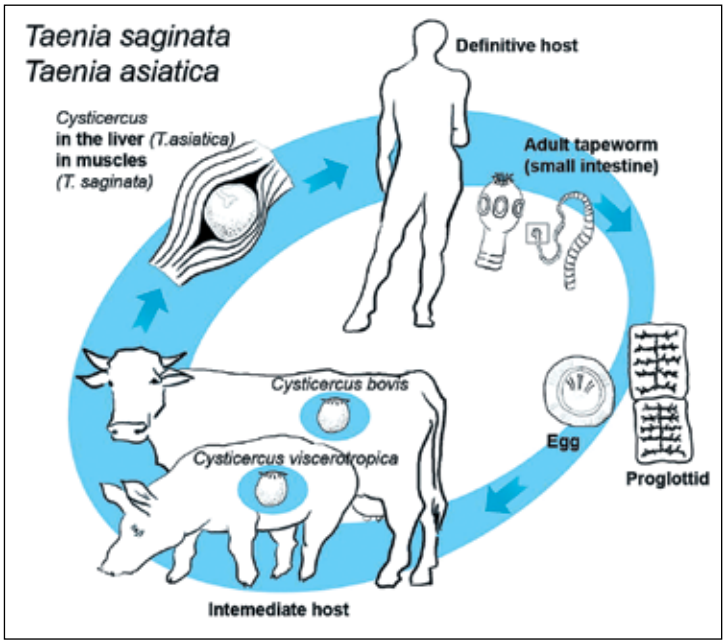

Fig. 2. Life cycle of *T. saginata* and *T. asiatica* (Kateřina Špůrková©)

Fig. 3. Cysticerci on the epicardial surface

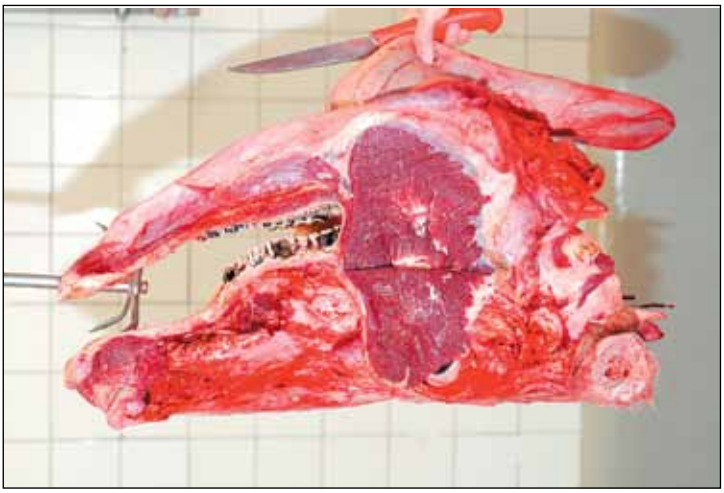

Fig. 4. Incisions into the bovine external masseter muscles

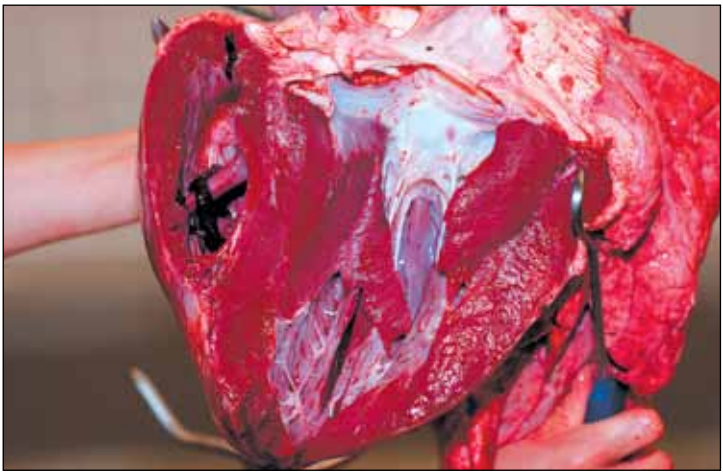

Fig. 5. Incisions into the heart