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Review Paper

Cerebral and non-cerebral coenurosis in small ruminants

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Abstract. Cerebral coenurosis is caused by *Coenurus cerebralis*, the larval stage of *Taenia multiceps*. The metacestode causes severe lesions in the brain and spinal cord of the intermediate host, so-called "gid" or "stagger" disease. Whereas, the non-cerebral coenurosis caused by *Coenurus gaigeri*, the larval stage of *Taenia gaigeri*, particularly affects goats. The cyst form of the *Taenia gaigeri* is found in intramuscular and subcutaneous tissues. The difference in the sequence of mitochondrial genes of *cox1* and *nadI* and also other variations reported for clinical, morphological and pathological aspects in coenurosis lead to the hypothesis that there is genetic intraspecific variability within this species, such as in other members of the genus *Taeni*a. Nevertheless, it has been shown that sheep and goats have been infected by both cerebral and non-cerebral coenurosis and it has been suggested that such cerebral and non-cerebral metacestodes may belong to different species of *Taenia* which are host specific for these hosts.

INTRODUCTION

Coenurosis, a fatal disease of sheep, is caused by the larval stage of *Taenia multiceps*. It is a parasitic disease that affects various livestock species, including ruminants, horses, pigs and human beings, worldwide. It is caused by *Coenurus cerebralis*, a bladder metacestode stage of *Taenia multiceps* (Leske, 1780), which inhabit the small intestine of dogs and wild carnivores as the definitive hosts (Abo-Shehada *et al.*, 2002; Acha & Szyfres, 2003; Ozmen *et al.*, 2005; Sharma & Chauhan, 2006; Christodoulopoulos, 2007; Avcioglu *et al.*, 2012). The cystic larvae are mainly found in the brain (Figs. 1 & 2) and in some instances in the spinal cord of small ruminants and to a lesser extent in cattle, resulting in neurological signs, such as gid, ataxia, head deviation and blindness. Such neurological signs, in the majority of cases, result in the death of the affected animals (Avcioglu *et al.*, 2011, 2012). Coenurosis have also been reported in man and horses (Herbert & Edwards, 1984; Achenef *et al.*, 1999).

There are reports from some of the Middle East countries of occurrence of a morphologically similar cyst to *C. cerebralis*, in sheep and goats, which reaches its maturity in locations outside the CNS, such as subcutaneous fascia, intramuscular (Fig. 3 & 4) and peritoneal areas (Fig. 5), which has been referred as *Taenia gaigeri* (Hall, 1919; Bhalla & Negi, 1962; Sing & Sing, 1972; Sharma *et al.*, 1995; Oryan *et al.*, 2010, 2012; Varcasia *et al.*, 2012). Location of the cysts in muscles may cause pain, muscular degeneration, necrosis and atrophy or result in impaired function of the involved organ particularly in severe infections.

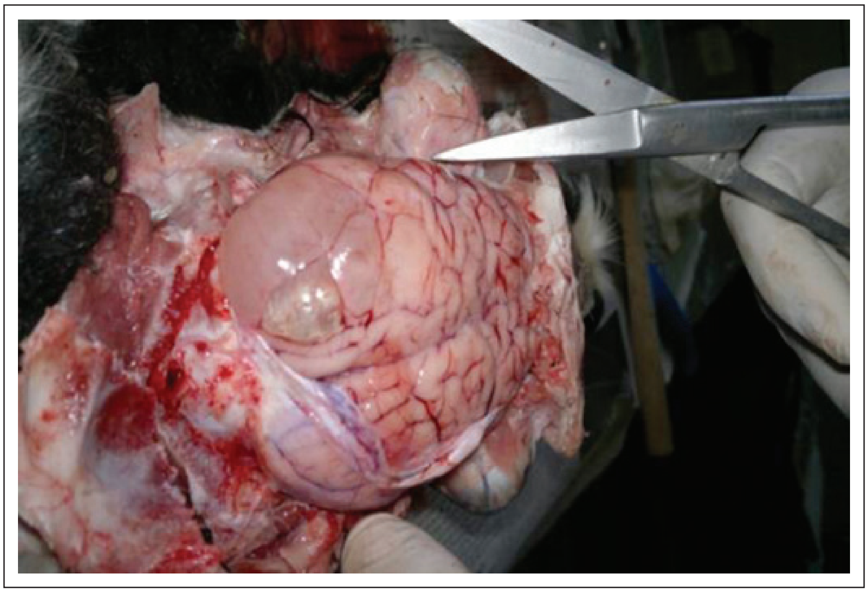

Figure 1. *Coenurus* cyst on the right lateral ventricle in the cerebral hemisphere. The cerebral gyri adjacent to the superficial compartment of *Coenurus* cyst have been flattened

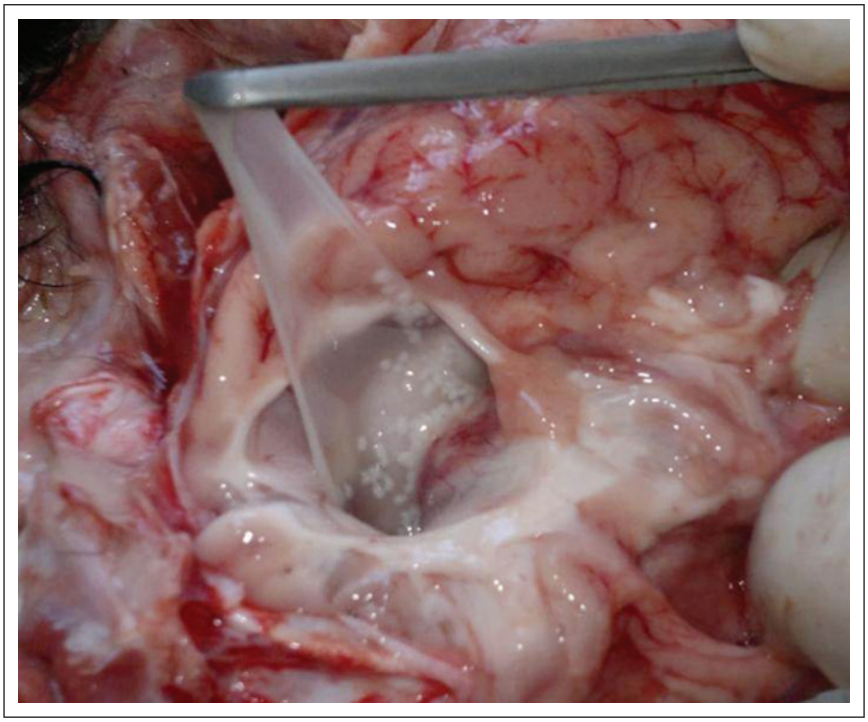

Figure 2. *Coenurus* cyst (arrow) on the left cerebral hemisphere in the 6 months old lamb

Figure 3. Two cysts of *C. gaigeri* are situated between the muscles of lumbar region of hind legs

Figure 4. A single interamuscular cyst of *C. gaigeri* is situated between the muscle fibers of the hind limb. The wall of the cyst is thin and translucent and the cyst is filled with a transparent water consistency fluid. The daughter cysts are tightly attached to the germinal layer and are not easily separated

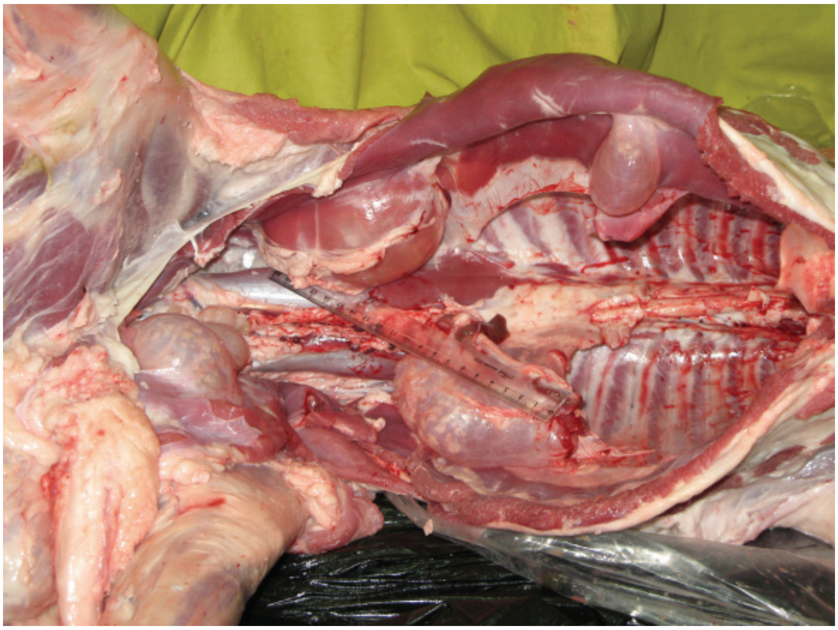

Figure 5. The cysts of *C. gaigeri* in the thoracic cavity of a sheep located in diaphragm and intercostal muscles

Prevalence

Coenurosis of the central nervous system has worldwide distribution; however, the rare occurring non-cerebral coenurosis have only been reported in some of the Asian countries, mostly those located in the Middle East. It has been reported that 2.9% sheep in Jordan (Abo-Shehada *et al.*, 2002), 2.9% in India (Varma & Malviya, 1989), 3%-7.3% in Iraq (Karim, 1979), 1.3% in Istanbul, Turkey (Akkaya & Vurusaner, 1998) and 3.1–28.5% in Kars Province of Turkey (Gicik *et al.*, 2007; Uslu & Guclu, 2007) have been infected with the cerebral form of the *C. cerebralis*. There are many reports regarding the cerebral form of the coenurosis in Europe, including in Wales (Herbert & Edwards, 1984), Ireland (Doherty & McAliister, 1989), Greece (Christodoulopoulos, 2007, Christodoulopoulos *et al.*, 2008) and France (Euzeby, 1966). The cerebral coenurosis has been reported from various parts of Italy such as Sardinia (Deiana, 1971; Scala *et al.*, 1992, 2007; Cancedda *et al.*, 2002; Ligios *et al.*, 2004), Apulia (Lia & Puccini, 1998; Troiano *et al.*, 1990), Sicily (Di Marco *et al.*, 1998; Guarda & Capucchio, 2002) and Latium (Tarantino *et al.*, 2002). The cerebral form of this metacestodosis has also been reported in Russia (Aminzhanov, 1988). Information regarding the prevalence of *C. cerebralis* is very rare in African countries and except two reports showing wide range of infection from 2.3% to 28.2% in sheep in Kenya no other epidemiological studies have been published in this area (Achenef *et al.*, 1999). *Coenurus cerebralis* has been reported in sheep, almost in all 31 provinces of Iran. Prevalence of 18.65% in West Azarbaijan Province, northwestern Iran (Tavassoli *et al.*, 2011), 0.007% in Kerman Province eastern Iran (Kheirandish *et al.*, 2012), 1.8% in Fars Province southeastern of Iran (Oryan *et al.*, 1994) have previously been reported in sheep.

Rare reports are available regarding the prevalence of *Coenurus gaigeri* infection. This form of metacestode has only been reported in goats and sheep and all these reports recorded higher prevalence of non-cerebral coenurosis in goats than sheep (Varma & Malviya, 1989; Gharagozlou *et al.*, 2003; Oryan *et al.*, 2010, 2012). Molecular and morphological evidences have shown that *T. gaigeri* and *C. gaigeri* are not separate species but are the same strain as *T. multiceps* and *C. cerebralis* (Oryan *et al.*, 2010; Varcasia *et al.*, 2012). Oryan *et al.* (2012) studied a total of 1050 sheep, 950 goats and 500 cattle slaughtered at Shiraz Slaughterhouse and reported the non-cerebral form of the cyst in 0.48% sheep and 1.79% goats. None of the cattle carcasses were infected with this metacestode. Prevalence of 0.09% *C. gaigeri* infection in goats in Kerman Province, eastern Iran by Kheirandish *et al.* (2012) and 2.6% in goats and 1.7% in sheep by Gharagozlou *et al.* (2003) in Tehran Province, central Iran have previously been reported. Prevalence of 1.1% to 2.41% of non-cerebral coenurosis in goats in India and 16% in goats in United Arab Emirates has previously been reported (Sadarnashipur & Lalgola, 1991; Sharma *et al.*, 1995; Godara *et al.*, 2011a; Varcasia *et al.*, 2012). This form of coenurosis has also been reported in Sudan (Ramadan *et al.*, 1973; Hago & Abu-Samra, 1980) and Oman (El Sinnari *et al.*, 1999).

Coenurosis has also been found in other animals such as cattle (Sanyal & Sinha, 1983; Yilmaz & Can, 1986; Yoshino & Momotani, 1988; Moghaddar *et al.*, 1992; Islam & Rahman, 1997; Varcasia *et al.*, 2013), wild sheep (Toofanian & Ivoghli, 1976), buffalo (Gupta & Chowdhury, 1985), yak (Samdup, 1993), horse, pig and man (Avcioglu *et al.*, 2011, Desouky *et al.*, 2011).

MORPHOLOGY AND LIFE CYCLE

The length of the adult *T. multiceps* is up to 100 cm. The scolex has four cup shaped suckers and bears a rostellum which has two rows of hooks (Fig. 6). The number of hooks in each scolex is variable, ranging from 22 to 32 (Fig. 7). The length of the large hooks has been recorded from 180 to 198 µm and the length of the small hooks ranges 108 to 126 µm (Soulsby, 1982; Desouky *et al.*, 2011). Although *T. gaigeri* is morphologically similar to *T. multiceps* but its scolex has one rostellum with a double crown of 24 to 28 hooks. The large hooks of *T. gaigeri* are 164 to 188.5 µm and the small hooks are 117 to 146 µm in length (Oge *et al.*, 2012). Oryan *et*

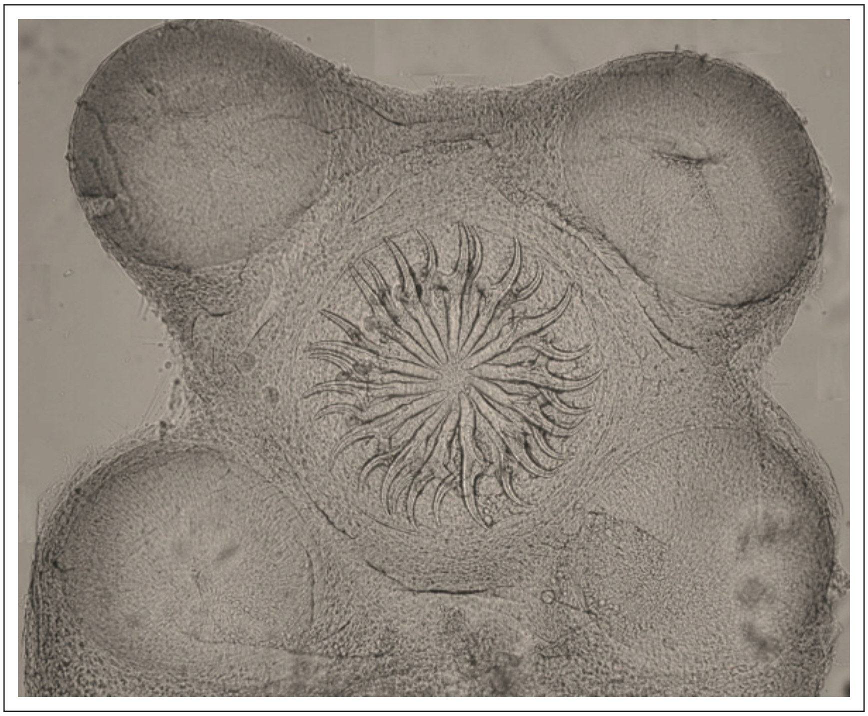

Figure 6. The scolex has four cup shaped suckers and bears a rostellum which has two rows of hooks

Figure 7. Two rows of rostellar hooks with small and large hooks are seen

Table 1. Comparison of *T.multiceps* and *T.gaigeri* based on the number and size of rostellar hooks

	Taenia multiceps			*Taenia gaigeri*				
	Hall (1919)	Loos-Frank (2000)	Desouky (2011)	Hall (1919)	Oryan (2010)	Schuster *et al.* (2010)	Oge (2012)	Varcasia (2012)
Number of hooks	22-32	20-34	18-34	28-32	28-32	26-32	24-28	26-32
Large hooks (µm)	150-170	120-190	180-198	160-180	128-196	145-180	164-188	145-180
Small hooks (µm)	90-130	73-160	108-126	115-150	106-122	100-125	117-146	114.4

al. (2010) have described that 28 to 32 hooks were arranged in two circles on the rostellum and the large and small hooks measured 128–169 µm and 106–122 µm, respectively. Varcasia *et al.* (2012) have reported that the rostellum of *T. gaigeri* had two rows of rostellar hooks with 26–32 small and large hooks and the large hooks were 159.6 µm and the small hooklets 114.4 µm long (Table 1).

Each *C. gaigeri* is lined by a thin hyaline layer, which, in turn, is enclosed by a fibrous connective tissue capsule of variable thickness that is infiltrated by few lymphocytes, eosinophils, and macrophages in the healthy normal cysts. In the lumen of each *C. gaigeri*, many scoleces are observed, each having a bladder wall, suckers and hooks (Fig. 8). Numerous mononuclear cells infiltrate the wall of the degenerating cysts and, in some cases, neutrophils diffusely infiltrate into the lumina of the degenerating cysts (Fig. 9). Therefore, it is possible that some microbial agents are transmitted by infective eggs and resulted in purulent inflammation in the lumen of the developing cyst in the intermittent hosts (Oryan *et al.*, 2010).

The *Coenurus* has unusual power of asexual division giving rise to 400-500 of protoscolices invaginated from the inner cysts wall so that large number of scolices which appear as white clusters are attached

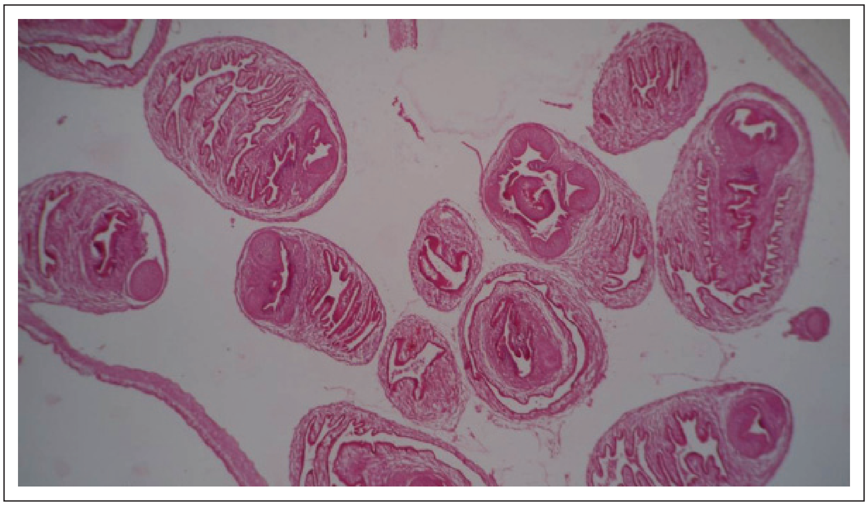

Figure 8. Section from a scolex of a metacestode of *C. gaigeri* showing bladder wall, suckers, and hooks

Figure 9. A degenerating scolex of *C. gaigeri* is seen. Neutrophils have diffusely been infiltrated inside the fibrotic scolex

to the internal layer of the wall of the superficial cyst (Soulsby, 1982; Nourani & Pirali Kheirabadi, 2009). However, Mohi el-Din (2010) indicated that the scolices are originated from the invaginated outer surface of the metacestode-wall and not from its inner germinal layer. Moreover, it has also been described that the scolices develop from the basal pole of the scolex-sac. The inner lining of the scolex-sac (derived from the outer surface of the metacestode-wall) extensively corrugate to increase its absorptive surface and form the outer absorptive surface of the adult cestode (Mohi el-Din, 2010).

The adult worm of the *T. multiceps* occur in the small intestine of dog, fox and coyote as the most frequent definitive hosts while the larval stage develops in the central nervous system of sheep and other ungulates (Scala *et al.*, 2007). One to three weeks after infection the metacestodes of this *Taenia* migrate via bloodstream to the central nervous system (CNS). However, it has been recently reported that this metacestode may develop in other organs such as intramuscular fascia, peritoneal cavity and subcutaneous tissues of goats and sheep. Such a metacestode that is morphologically comparable to the central nervous system form has been called *C. gaigeri* and its adult form *T. gaigeri*. However, no experimental study has been conducted to elucidate whether these two metacestodes belong to the same origin or they are originated from two different cestodes. Further ultrastructural, biochemical and molecular studies on the experimentally infected dogs with the metacestodes, and goats and sheep with the eggs of cerebral and non-cerebral coenurosis can possibly answer this question. As there are no reports on the occurrence of *C. gaigeri* in other herbivores, it is also suggested to experimentally infect cattle, buffaloes, camel and horse and check for the occurrence of non-cerebral form of this metacestode in these animals.

The eggs are passed in faeces of the infected dog; they are immediately infective and on ingestion by herbivores the oncospheres spread from the eggs. The oncospheres are carried in blood circulation to migrate to the brain and spinal cord and/or possibly to intramuscular and visceral organs and subcutaneous tissues. The *Coenurus* cysts develop slowly over several months to become mature in six to eight months and result in the onset of clinical signs. As the cyst matures, it develops into a large, delicate, thin translucent fluid containing cyst, measuring commonly about 5-6 cm in diameter. Dogs are frequently fed on the viscera and heads containing cerebral and non-cerebral coenuri and they are not usually treated with anthelmintics. Approximately 42-60 days after ingesting the *Coenurus* cysts by dogs the adult tapeworm develops in the duodenum and jejunum and the life cycle is completed.

CLINICAL SIGNS AND PATHOGENESIS

The cerebral form of the coenurosis is referred to as acute or chronic gid or sturdy; however the chronic form is more common. Acute coenurosis occurs as the result of larval migration in the central nervous system when several viable eggs are ingested by a herbivore animal. Chronic coenurosis mostly occurs in older animals of more than 6 months age, where it presents as a consequence of cyst development and slowly create local lesion in the cerebrum, cerebellum and spinal cord. However, it typically involves one cerebral hemisphere and to a lesser extent the cerebellum. Although it has been reported that only those parasites which reach the central nervous system develop to form metacestodes (Bussell & Kinder, 1997; Mohi El-Din, 2010), but there are few reports that similar cysts have developed in musculoskeletal system, visceral organs and subcutaneous connective tissue of goats and in a lesser extent in sheep.

It has been stated that those oncospheres which reach different organs other than central nervous system disappear and do not reach maturity, probably because of immune mechanisms of the intermediate host or absence of the CSF. The neurological signs depend on the location, number and size of the cyst(s) in the CNS (Achenef *et al.*, 1999). The affected animal holds its head to one side and turn in a circle toward the cyst's location. However, occurrence of coenurosis in CNS leads to other neurological symptoms such as ataxia, incoordination, drowsiness, head pressing, blindness and coma and usually results in death of the infected animal within several weeks. When the metacestode localizes in spinal cord it results in progressive paresis or hind leg's paralysis.

Christodoulopoulos (2007) reported two uncommon clinical forms of coenurosis in sheep. The first case, having *C. cerebralis* cyst in the brainstem, was an 11 months old sheep having partial paroxysm disorder. The animal laid down in lateral recumbency displaying initially a stuporous condition and subsequently began to revolve its head from the atlanto-occipital joint. The second case, a 6–7 weeks old lamb, which showed concomitant bacterial purulent meningo-encephalitis together with *C. cerebralis* cysts in brain hemisphere, displayed lateral recumbency with seizure activity.

In addition, the larval stage also develops in intramuscular and subcutaneous regions. Similar cysts have also been reported in peritoneal and pelvic cavities (Oryan *et al.*, 2012), liver (Godara *et al.*, 2011a), the skeletal muscles including thigh, biceps femoris, forelimb muscles (triceps), and muscles of the head, neck, thorax, and abdomen in goats (Patro *et al.*, 1997; Gharagozlou *et al.*, 2003; Ghosh *et al.*, 2005; Oryan *et al.*, 2010, 2012). Gharagozlou *et al.* (2003) described pulmonary coenurosis and Kheirandish *et al.* (2012) reported the occurrence of *C. gaigeri* in the tongue, parotid area and tunica adventitia of the aorta in goats. The mild to moderate forms of the non-cerebral coenurosis do not show specific clinical signs and are not clinically detectable and the cysts are found in the slaughterhouse. However, non-cerebral coenurosis has also been reported in sheep but with lesser extent (Oryan *et al.*, 2012; Christodoulopoulos *et al.*, 2013). The cysts have been located in the triceps brachii muscle, diaphragm, infraspinatus muscle of the shoulder, muscles of the thigh, abdomen and ommentum. No clinical evidence of the non-cerebral coenurosis had been recorded during the antemortem veterinary inspection of the infected sheep (Christodoulopoulos *et al.*, 2013). However, in severe cases lameness, paresis and paralysis together with outgrowing skin lumps, due to the subcutaneous cysts, are the major clinical manifestation of this disease (Ramadan *et al.*, 1973; Oryan *et al.*, 2010, 2012).

Diagnosis of the cerebral coenurosis is dependent on the clinical manifestations, neurological examination, ultrasound examination and post-mortem examination (Godara *et al.*, 2011b; Biswas, 2013). Nevertheless, interpretation of the clinical signs in combination with detailed location of the cyst, using ultrasound examination, is the best method of diagnosis (Skerritt & Stallbaumer, 1984; Tirgari *et al.*, 1987; Biswas, 2013).

Listeriosis, nasal bots syndrome, louping-ill, scrapie, sarcocystosis, brain abscessation, polioencephalomalacia and cerebral echinococcosis should be considered as the differential diagnosis of the cerebral coenurosis (Achenef *et al.*, 1999; Godara *et al.*, 2011b; Scott, 2012). Treatment of the cerebral coenurosis includes chemo-therapy with antiparasitic drugs and surgery. The surgical treatment of coenurosis in small ruminants is limited and is not recommendable in field conditions. Although the surgical treatment of cerebral coenurosis has not been found successful in some instances (Soulsby, 1982), but several reports have indicated that surgical treatment is still the most effective method for cerebral coenurosis and had successful rate of more than 70 percent (Skerritt & Stallbaumer, 1984; Komnenou *et al.*, 2000; Biswas, 2013). However, surgery of the skulls and brains of sheep with cerebral coenurosis would be effective up to 90%, if the brain and skull are first tested by MRI or ultrasonography (Manunata *et al.*, 2012). Ghazaei (2007) indicated that, fenbendazole and praziquantel were effective against the cerebral coenurosis. He also showed that the best result was obtained by administering albendazole and a combination of fenbendazole together with praziquantel. It has been shown that praziquantel administration with dosage rates of 50 to 500 mg/kg resulted in successful treatment of this metacestode (Verster & Tustin, 1990). Chemotherapy could be applied only in migration stages of the parasite, because when the *Coenurus* is formed, rupture of the cyst after treatment could be very dangerous. The efficacy of the antiparasitic drugs such as albendazole, fenbendazole, and praziquantel against cerebral coenurosis was supported by other studies too (Eslami

& Bazargani, 1986; Aminzhanov, 1988). No specific therapeutic strategies have been applied as yet for the non-cerebral coenurosis.

PUBLIC HEALTH IMPORTANCE

Cerebral and non-cerebral coenurosis are zoonotic diseases and there are more than 100 reports of human infection with these metacestodes. The cerebral coenurosis create serious problems and even death in patients (Backer & Jacobson, 1951). Ing *et al.* (1998) reported the cerebral coenurosis in a girl with extensive central nervous system involvement in North America. *Coenurus* cysts have also been reported in human muscles (Debrie *et al.*, 1982; Kurtycz *et al.*, 1983) and eyes. The ocular coenurosis resulted in endophthalmy, retinal damage and blindness (Ibechukwu & Onwukeme, 1991; Ing *et al.*, 1998). Ing *et al.* (1998) have also reported an intramuscular *Coenurus* cyst in a man in North America.

HISTOPATHOLOGICAL FINDINGS

The affected cerebral hemisphere reveals multiple scolices growing on the internal layer of the cyst. Such developing cerebral cysts are accompanied with increased intracranial pressure and thinning the cerebral grey and white matter and in some instances the skull. The cerebral tissues around the *Coenurus* cyst show neuronal degeneration, demyelination, necrosis, hyperemia, perivascular cuffing, diffuse astrocytosis and microgliosis leading to formation of microglial nodules (Gogoi *et al.*, 1991; Tafti *et al.*, 1997; Sharma *et al.*, 1998) and pressure atrophy in the skull (Gogoi *et al.*, 1991; Sharma & Chauhan, 2006; Nourani & Pirali Kheirabadi, 2009; Kheirandish *et al.*, 2012). Godara *et al.* (2011a) reported liquifactive necrosis around the cerebral cysts due to degenerative changes, with satellitosis, neuronophagia and diffuse gliosis. The meninges of the infected animals were hyperemic and edematous. No capsule of fibrous connective tissue enclosed the cerebral form of *Coenurus*.

However, Oryan *et al.* (2010) recorded that each *C. gaigeri* was covered by a thin layer of hyaline, which, in turn, was enclosed by a fibrous connective tissue capsule of variable thickness. This fibrous connective tissue capsule and its surrounding muscle fibers were infiltrated by a few lymphocytes, eosinophils, and macrophages in the healthy normal cysts and by severe acute or chronic inflammatory cell infiltration in cases of degenerating or contaminated *C. gaigeri*. Focal to diffuse inflammatory cell infiltration of mononuclear and polymorphonuclear cells in the surrounding fibrous connective tissue and the hylinized layer of the non-cerebral coenurosis has also been reported by other investigators (Kheirandish *et al.*, 2012). The pathological changes in the tissues surrounding the non-cerebral cysts are initiated by mechanical destruction of the affected tissues and are associated with degenerative and necrotic changes and inflammatory reactions with infiltration of eosinophils, lymphocytes, and plasma cells together with repair of the surrounding tissues by proliferation of the fibroblasts and endothelial cells.

It has been reported that the *Coenurus* cysts in lung has been associated with atelectasis and focal interstitial fibrosis in the pulmonary parenchyma around the cyst (Kheirandish *et al.*, 2012) and the hepatic coenurosis resulted in pressure atrophy of the hepatic lobules and dilatation of the sinusoids (Godara *et al.*, 2011a).

MOLECULAR ASSAYS

DNA sequence variability between the cerebral and non-cerebral forms has been investigated within the *cox1* (HM101469, Cytochrome *c* subunit 1) and *nadI* (HM101470, NADH dehydrogenase I) mitochondrial genes (Oryan *et al.*, 2010). Such a methodology has previously been successfully used for diagnosis of other cestodes (Gasser *et al.*, 1999). For the first time, Scala & Varcasia (2006) designed the primers for the mitochondrial genome *cox1* and *nadI*. Several samples were obtained from different geographic areas of Italy and compared through the sequencing of the mitochondrial genes. Pairwise comparison between the *nadI* sequences of the *T. multiceps* isolates showed differences ranging from 1.27% to 2.54%, using an isolate obtained from Wales as an outgroup, while the *cox1* sequences within the samples coming from Sardinia showed a lesser degree of variability, ranging from 0.22% to 0.67%. According to the two genes, they determined 3 specific genetic variants, termed Tm1 (GenBank: DQ309767/AY669089), Tm2 (GenBank: DQ309768/DQ309770) and Tm3 (GenBank: DQ309769/DQ077820), in Sardinian samples.

Pairwise comparison between the *nadI* sequences of the *T. multiceps* isolates of cattle from Erzurum and other *T. multiceps* isolates showed differences ranging from 0.6 to 2.9%, while *cox1* sequences aligned with the same methodology showed differences ranging from 0.2 to 2.6%. According to the two genes, three isolates were described in cattle from Erzurum Province and were termed Erzurum 1 (GenBank: HM143882/HM143883), Erzurum 2 (GenBank: HM143884/HM143885) and Erzurum 3 (GenBank: HM143886/HM143887) (Avicoglu *et al.*, 2011).

The sequences of *cox1* and *nadI* subunits of *C. gaigeri* have been compared with those of *T. multiceps*. Pairwise comparison between the *nadI* sequences of the cerebral *Coenurus* and non-cerebral *Coenurus* and the other *T. multiceps* genotypes existing in GenBank have showed differences. Oryan *et al.* (2010) reported *cox1* sequences of the Iranian non-cerebral coenuri of goat (GenBank: HM101469/HM101470) and other *T. multiceps* (cerebral *Coenurus*) genotypes available in GenBank and showed variability ranging from 0.76 to 1.06%, and *nadI* sequences demonstrated a more degree of diversity, ranging from 0.87 to 1.97%.

Varcasia *et al.* (2012) sequenced the mitochondrial partial *cox1* and *nadI* genes of the non-cerebral coenuri of goat (GenBank: FR873148) in United Arab Emirates. They indicated a pairwise distance of 1.0–1.3% and 2.4–4.1% degree of diversity compared with the parasite *cox1* sequences from Italy (Tm1–Tm3 strains) and Erzurum strains of ovine origin, respectively; whereas it had 0.6–1.3% and 0.4–1.1% pairwise distance for *nadI*. In addition, Varcasia *et al.* (2013) described molecular homology by *nadI* and *cox1* sequencing of bovine cerebral coenurosis in Sardinia of Italy. They showed the DNA of the *T. multiceps* specimens found in Sardinian cattle had 100% homology with the Tm2 sheep strain of *T. multiceps*, according to the classification by Scala & Varcasia (2006) (Table 2).

CONCLUSION

Coenurosis, as well known metacestodosis, are not only zoonotic but are also important parasitic disease which cause severe tissue damage, reduction in production, losses in breeding and considerable economic loss due to condemnation of the infected organs of the herbivorous animals and even death of the animals in cases of heavy infestations (Radfar *et al.*, 2005). This disease is found mainly in sheep and goats at an incidence of 0.09 – 18.65% at different areas of Iran (Oryan *et al.*, 2010; Tavassoli *et al.*, 2011; Kheirandish *et al.*, 2012). Coenurosis is one of the most common diseases of the central

Table 2. Pairwise comparison between the *nadI* and *cox1* sequences of the cerebral *Coenurus* and non-cerebral *Coenurus*

	Cerebral *Coenurus*		Non-cerebral *Coenurus*	
	Scala & Varcasia (2006)	Avcioglu (2011)	Oryan (2010)	Varcasia (2012)
nadI	1.27 – 2.54	0.6 – 2.9	0.87 – 1.97	0.4 – 1.7
cox1	0.22 – 0.67	0.2 – 2.6	0.76 – 1.06	1 – 4.1

nervous system in sheep in Italy (Scala & Varcasia, 2006).

Coenurosis has been reported from different parts of the body. Normally the cysts are found in the central nervous system of sheep and goats; however in some instances the *Coenurus* cysts have also been reported from extra-cranial locations, uncommon sites, including body cavities, abdominal muscles, perineal fat, tongue, parotid area, lungs and tunica adventitia of the aorta (Gharagozlou *et al.*, 2003; Kheirandish *et al.*, 2012). Simultaneous coenuri have also been reported in the brain and liver in a goat (Godara *et al.*, 2011a). Literature reports that infection with the coenuri is not usually correlated with age and season, while the sizes of the cysts are positively correlated with the number of cysts (Cancedda *et al.*, 2002).

Scanty difference has been shown between the two Taeniid subtypes regarding the sequences of *cox1* and *nadI* genome. This finding supports the hypothesis that *C. cerebralis* and *C. gaigeri* are not different species. The above mentioned difference in the sequence of mitochondrial genes of *cox1* and *nadI* and also other variations reported for clinical, morphological and pathological aspects in coenurosis lead us to hypothesize the presence of genetic intraspecific variability within this species, such as in other members of the genus *Taenia*. The intraspecific sequence variation within the *T. multiceps* and *T. gaigeri* show the capacity of these Taeniids to rapidly adapt to new intermediate host species, as well as sites of infection occupied by the larval stages in different hosts (Oryan *et al.*, 2010). Considering the two genes, it has been possible to define number of the specific genetic variants in samples so that they have been termed Tm1, Tm2, Tm3 and Erzurum 1, Erzurum 2 and Erzurum 3.

Nevertheless, it has been shown that goats and sheep have been infected by both cerebral and non-cerebral coenurosis but it is not clear whether such a cerebral and non-cerebral metacestode belong to different species of *Taenia* or they are identical but adapted specifically to a tissue/organ of a specific host. New experimental works, using the intermediate and final hosts, should answer the similarities and differences in the molecular structure and distribution pattern of these metacestodes.

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