Characteristics of non-cerebral coenurosis in tropical goats

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\textbf{A B S T R A C T}

The epidemiological, clinical, and biochemical profile of non-cerebral coenurosis in goats and the morphological characteristics of the responsible metacestodes (cysts) were examined in a cross-sectional survey of slaughtered goats in abattoirs of the United Arab Emirates (U.A.E.) originating from Abu Dhabi and various tropical countries. The age, country of origin, and location of each cyst in the body of goats were recorded. Blood samples collected from infected and matching healthy goats were subjected to biochemical analysis. Data on the morphological characteristics of the cysts as well as the clusters, scoleces, and rostellar hooks in one cyst from each affected carcass were collected. The data collected were subjected to statistical analysis. A total of 2,384 slaughtered goats were examined and 40 goats were diagnosed as infected with non-cerebral coenurus cysts. The prevalence of non-cerebral coenurosis was 1.75% and the degree of parasite aggregation \( k \) was 0.003, which is indicative of overdispersion \( (k < 1) \). The only abnormalities observed in the infected goats were palpation of large single cysts in thigh muscles and higher serum aspartate aminotransferase (AST) value. A total of 76 non-cerebral coenurus cysts from 14 different body locations were collected. No cysts were found in the brain or spinal cord. Cysts located in psoas muscles had on average significantly bigger volumes and higher numbers of scoleces and clusters compared to cysts located in other body parts \((P\text{-value}=0.000)\). Significant differences in the morphometric measurements of the rostellar hooks were observed between cysts found in goats from different countries of origin \((P\text{-value} < 0.05)\) perhaps due to initial steps of allopatric speciation by geographic isolation. A significant positive correlation was found between number of scoleces and volume of cysts \((b = 6.37 > 5; R - \text{Sq} = 89.4\%; P\text{-value}=0.000)\) and between number of clusters and number of scoleces \((b = 25.13 > 1; R - \text{Sq} = 79.8\%; P\text{-value}=0.000)\) indicative of following a positive allometric growth as well as between number of clusters and volume of cysts \((b = 0.25 < 0.5; R - \text{Sq} = 69.4\%; P\text{-value}=0.000)\) indicative of following a negative allometric growth. The biological significance of the observed allometries is not known, but perhaps for evolutionary reasons the parasite is investing its resources more on the growth of scoleces, less on the growth of cyst volume, and even less on the number of clusters.

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1. Introduction

The term “non-cerebral coenurosis” refers to the occurrence of coenurus cysts in body locations of the host other than the brain and the spinal cord. Non-cerebral coenurosis was first described in sheep (Benkovskij, 1899) and then in goats (Gaiger, 1907). The parasite responsible for non-cerebral coenurosis was initially named \textit{Multiceps gaigeri} (Hall, 1916) in goats, and \textit{M. skrjabini} (Popov, 1937) in sheep (Schuster et al., 2010). However, the later literature considered \textit{M. gaigeri} as the same species with \textit{T. multiceps}, while \textit{M. skrjabini} was rather treated as an unknown entity (Verster, 1969; Soulsby, 1982; Loos-Frank, 2000; Smith and Sherman, 2009).

Recently, the occurrence of non-cerebral coenurosis in sheep has been confirmed (Christodoulopoulos et al., 2013); while the geographical distribution of the disease in both goats and sheep covers a wide range of tropical countries in Asia, Middle East and Africa (Sharma et al., 1995; Sharma and Chauhan, 2006; Oryan et al., 2010; Schuster et al., 2010; Christodoulopoulos et al., 2013). Furthermore, investigation of two mitochondrial genes (CO1 and ND1) supported the opinion that \textit{M. gaigeri} belongs to the same species of...
T. multiceps and only an intraspecific variation was noted between them (Oryan et al., 2010; Varcasia et al., 2012).

The lack of systematic information on non-cerebral coenurosis in goats was the rationale for undertaking a cross-sectional abattoir survey of non-cerebral coenurus cysts in goats in Abu Dhabi (United Arab Emirates). The objective of the present study was to investigate the epidemiological, clinical, and biochemical profile of non-cerebral coenurosis in goats and the morphological characteristics of the responsible metacestodes (cysts).

2. Material and methods

2.1. Goats

Non-cerebral coenurus cysts were collected from slaughtered goats in three abattoirs namely Bawadi, Falaj-Hazaa, and Yahar in the city of Al Ain of the Abu Dhabi Emirate of the United Arab Emirates (U.A.E.) during January 2011-August 2013. The majority of goats had been imported from various neighbouring countries for slaughtering.

2.2. Ante-mortem clinical examination of goats

All goats were given a full clinical examination before slaughter, including measurements of temperature, heart, and respiratory rate. In addition, the major groups of muscles were palpated in order to detect possible swelling or pain.

2.3. Cyst and data collection

The carcass of slaughtered goats was inspected by visual examination as well as by palpation. The suspected cyst was removed by dissecting the surrounding tissue. If a coenurus cyst was suspected in the carcass, the brain and the spinal cord were also examined visually for the presence of coenurus cysts by dissecting the head and splitting the carcass in half respectively using the saw of the slaughterhouse.

Cysts suspected as coenurus were removed, placed in a labelled plastic bag, and transferred to the laboratory in a portable fridge at 4–8 °C within an hour. In addition, the following data were recorded for goats with suspected coenurus cysts: age, country of origin, and location of each cyst in the body.

2.4. Blood samples

Following the usual ante-mortem clinical inspection of the goats, a 5 ml and a 10 ml blood sample were collected by jugular venipuncture in test tubes with and without heparin respectively. Goats, a 5 ml and a 10 ml blood sample were collected by jugular venipuncture in test tubes with and without heparin respectively.

2.5. Biochemical analysis

Blood serum albumin (Doumas et al., 1971) and total proteins (Weichselbaum, 1946) were determined using colorimetric methods. Serum aspartate aminotransferase (AST) (Bergmeyer et al., 1986), gamma-glutamyl transpeptidase (GGT) and creatine kinase (CK) (Szasz et al., 1976) were determined using enzymatic kinetic methods. All measurements were assayed at 37 °C by means of the same spectrophotometer (Shimatzu UV-1601, Tokyo, Japan). In order to exclude the possibility of selenium deficiency which may affect CK, selenium determination was carried out in whole blood by a fluorometric method in a spectrofluorometer (Hitachi Model F-2000) (Christodoulopoulos et al., 2003). The laboratory normal reference values for serum albumin, total proteins, AST, GGT, and CK were 24–44 g/l, 64–78 g/l, 58–350 IU/l, 5–89 IU/l and 20–194 IU/l, respectively. The threshold selenium concentration in whole blood below which goats were considered selenium deficient was 0.07 mg/dl (McComb et al., 2010).

2.6. Examination of cysts

The cysts collected during carcass inspection were examined to confirm their identity and measure their morphological characteristics. A cyst was initially identified as a coenurus cyst when it contained a bladder filled with a watery fluid and having a thin and transparent wall with numerous scoleces attached to its inner surface.

The morphological characteristics of each cyst were measured by establishing its volume by placing it in a measuring cylinder filled with tap water and by laying it on a flat surface and counting the number of scoleces and their arrangement in clusters. As cluster was considered any group of scoleces attached in the cyst membrane in proximity and surrounded by a distinguished area of membrane that was free of scoleces; random, single scoleces surrounded by a distinguished area of membrane free of scoleces were ignored.

For the final confirmation of the identification, a piece of the larval membrane containing a cluster of scoleces was placed on a slide along with some drops of normal saline. A cover slip was pressed tightly on the slide to provoke the evagination of the scoleces and the scoleces of the cluster were examined under a light microscope. The identification of the coenurus larvae was based on the recognition of the rostellar hooks along with the four surrounding suckers in the evaginated scoleces (Soulsby, 1968; Loos-Frank, 2000 Loos-Frank, 2000).

2.7. Examination of rostellar hooks

The rostellar hooks were further examined in one cyst from each affected carcass. For this purpose, five to eight scoleces of each cyst, randomly selected, were cut and placed face down on slides (the top was placed downwards, while the extremity previously attached to the larval membrane was placed upwards). Some drops of Berlèse solution (cleaning and mounting medium; TCS biosciences, United Kingdom) were added and a cover slip was placed and pressed on each scolex rigorously. The slides were left to dry for 1–2 h and subsequently were observed under a light microscope.

Some of the rostella were posing in the scoleces in such a way that permitted the counting of the total number of small and large hooks (Fig. 1). Only these rostella were used for counting the number of hooks and measuring the dimensions of the rostellar hooks. In case that no rostellum was properly posing, the process was repeated with new scoleces until one rostellum at least from each cyst allowed the proper counting of the hooks.

The measurement of the dimensions of the hooks was accomplished by photographing the rostellum with a digital camera coupled to a light microscope. Measurement of the dimensions was performed using a computerized image analysis system (ImageJ by Softonic®). The accuracy of the measuring method had been previously tested by measuring a scale of known length (10 μm) fixed next to a scolex. Only hooks lying completely ‘en face’, were measured. Seven morphometric measurements were performed on each scolex: Sum of large and small hooks per scolex, length of large hook, length of handle of large hook, length of blade of large hook,
Table 1  
Epidemiological profile and morphological characteristics of non-cerebral coenurosis cysts in goats.

<table>
<thead>
<tr>
<th>Country of origin</th>
<th>Number of goats</th>
<th>Average age of goats in months (range)</th>
<th>Total number of cysts</th>
<th>Mean intensity of cysts/goat (Range)</th>
<th>Body location in goats</th>
<th>Average volume of cysts in ml (range)</th>
<th>Average number of scoleces/cyst (range)</th>
<th>Average number of clusters/cyst (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAE</td>
<td>2</td>
<td>13.0 (2–≥24)</td>
<td>3</td>
<td>1.5 (1–2)</td>
<td>Brachial biceps (1), diaphragm (1), muscles of thigh (1)</td>
<td>6.3 (4–8)</td>
<td>58.7 (23–110)</td>
<td>7 (5–8)</td>
</tr>
<tr>
<td>Iran</td>
<td>11</td>
<td>3.8 (2–12)</td>
<td>29</td>
<td>2.6 (1–11)</td>
<td>Abdominal muscles (3), brachial biceps (1), infraspinatus muscle (2), intercostal muscles (1), lumbal muscles (1), muscles of antebrachium (1), muscles of thigh (6), myocardium (1), omentum (3), pariental pleura (3), perirenal fat (3), psoas muscle (2), triceps brachii muscle (2)</td>
<td>12.4 (1–125)</td>
<td>76.7 (4–782)</td>
<td>7.5 (1–30)</td>
</tr>
<tr>
<td>Oman</td>
<td>8</td>
<td>4.5 (2–18)</td>
<td>9</td>
<td>1.1 (1–2)</td>
<td>Abdominal muscles (3), brachial biceps (2), infraspinatus muscle (1), muscles of thigh (1), pariental pleura (1), perirenal fat (1)</td>
<td>5.9 (3–9)</td>
<td>42.1 (16–104)</td>
<td>7 (4–10)</td>
</tr>
<tr>
<td>India</td>
<td>8</td>
<td>5.4 (2–≥24)</td>
<td>15</td>
<td>1.9 (1–8)</td>
<td>Abdominal muscles (2), infraspinatus muscle (1), lumbal muscles (2), muscles of thigh (2), myocardium (1), omentum (2), pariental pleura (1), perirenal fat (1), psoas muscle (1), triceps brachii muscle (2)</td>
<td>10.2 (2–70)</td>
<td>79.3 (5–455)</td>
<td>7.2 (2–24)</td>
</tr>
<tr>
<td>Sudan</td>
<td>7</td>
<td>3.0 (2–4)</td>
<td>13</td>
<td>1.9 (1–4)</td>
<td>Abdominal muscles (2), brachial biceps (1), infraspinatus muscle (1), muscles of thigh (3), myocardium (1), omentum (1), pariental pleura (1), perirenal fat (1), triceps brachii muscle (2)</td>
<td>5.2 (1–13)</td>
<td>32.2 (5–102)</td>
<td>5.7 (1–12)</td>
</tr>
<tr>
<td>Yemen</td>
<td>4</td>
<td>11.5 (2–≥24)</td>
<td>7</td>
<td>1.8 (1–4)</td>
<td>Abdominal muscles (1), infraspinatus muscle (1), muscles of antebrachium (1), muscles of thigh (2), omentum (1), perirenal fat (1)</td>
<td>6.1 (2–15)</td>
<td>45.1 (14–125)</td>
<td>6.3 (1–12)</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>5.4 (2–≥24)</td>
<td>76</td>
<td>1.9 (1–11)</td>
<td></td>
<td>9.2 (1–125)</td>
<td>61.9 (4–782)</td>
<td>6.9 (1–30)</td>
</tr>
</tbody>
</table>
length of small hook, length of handle of small hook, and length of blade of small hook (Fig. 2).

2.8 Statistical analysis

The terms used to describe parasite distribution were those of Margolis et al. (1982) where prevalence is the proportion of infected hosts and mean intensity is the mean number of parasites per infected host. The prevalence and the degree of parasite aggregation (k) were estimated as described by Permin et al. (1999).

The data collected were analyzed using descriptive statistics for calculating the averages and standard deviations of continuous variables and the frequencies and percentages of discrete variables. One-way analysis of variance was used to determine the relationship between: (i) cyst characteristics or morphometric measurements of scoleces with origin of animal, (ii) cyst characteristics with cyst position in body, and (iii) infection status of animals with blood biochemical values. Linear regression was used to determine the relationship between cyst characteristics with age of animal and regression analysis was used to determine the relationship between cyst characteristics with morphometric measurements of scoleces.

The growth of the cysts in relation to their scoleces was characterized as isometric, positive, or negative allometric by determining whether the slope (b) of the relative regression line was equal, larger, or smaller than the value of b predicted for isometry. The value of b for isometry was obtained by dividing the rate of change on the y-axis by the rate of change on the x-axis of the regression line ($b = \Delta \Omega / \Delta X$).

The level of significance for the statistical analyses performed was set at 5% and all calculations were conducted using the statistical package Minitab for Windows (Minitab 16, Professional).

3. Results

A total of 2,284 slaughtered goats aged 2 to ≥24 months (average 4.9 months) were examined and 40 goats (Table 1) were conclusively diagnosed as infected with non-cerebral coenurus cysts. The prevalence of non-cerebral coenurosis in the present survey was thus 1.75%. The degree of parasite aggregation (k) was 0.003. Most of the infected goats were 2 month (47.5%) and 4 month (22.5%) old. Only 2 out of the 40 infected goats originated locally from U.A.E., the rest had been imported from Iran (11), Oman (8), India (8), Sudan (7) and Yemen (4).

During ante-mortem clinical examination with palpation a hard mass was detected in the thigh muscles of five young goats. No evidence of pain was noticed during the palpation of the hard mass in these animals. A large coenurus cyst was revealed in each of these five animals during the post-mortem examination with volumes ranging 15–37 cm$^3$. The coenurus cysts in the remaining animals were not detectable by palpation. No other clinical signs connected to the disease were noticed during clinical examination.

Table 2 shows the results of the blood biochemical analysis of goats infected with non-cerebral coenurosis and uninfected goats. All test values for both infected and uninfected goats were within normal range. No significant differences in test values between infected and uninfected goats were observed except for AST. Infected goats had on average a higher AST value (202.73 IU/l) compared to uninfected goats (141.18 IU/l) (Table 2). Goats with high activity AST had no evidences for any other liver or muscular abnormality. A total of 76 non-cerebral coenurus cysts were collected at the abattoirs from the 40 infected goats. The body location of the cysts were abdominal muscles, brachial biceps, diahragma, infraspinatus muscle, intercostal muscles, lumbal muscles, muscles of antebrachium, muscles of thigh, myocardium, omentum, pariental pleura, perirenal fat, psoas muscle, and triceps brachii muscle. No cysts were found in the brain or spinal cord in any of the 40 infected goats (P-value = 0.000). The most frequent body locations of the non-cerebral cysts were muscles of thigh (19.7%) followed by abdominal muscles (14.5%) and omentum (9.2%), while diahragma (1.3%) and intercostal muscles (1.3%) were the body locations of the cysts.

### Table 2

Blood biochemical profile of goats infected with non-cerebral coenurosis and uninfected goats.

<table>
<thead>
<tr>
<th>Test</th>
<th>Normal value</th>
<th>Average ± std</th>
<th>Infected (n = 40)</th>
<th>Uninfected (n = 40)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albumin</td>
<td>24–44 g/l</td>
<td>41.35 ± 6.51</td>
<td>42.38 ± 6.33</td>
<td>0.477</td>
<td></td>
</tr>
<tr>
<td>Total proteins</td>
<td>64–78 g/l</td>
<td>70.13 ± 5.20</td>
<td>70.43 ± 5.14</td>
<td>0.796</td>
<td></td>
</tr>
<tr>
<td>AST</td>
<td>58–350 IU/l</td>
<td>202.73 ± 100.39</td>
<td>141.18 ± 42.52</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>GGT</td>
<td>5–89 IU/l</td>
<td>35.33 ± 7.89</td>
<td>33.78 ± 7.86</td>
<td>0.381</td>
<td></td>
</tr>
<tr>
<td>CK</td>
<td>20–194 IU/l</td>
<td>159.75 ± 164.62</td>
<td>108.73 ± 42.54</td>
<td>0.061</td>
<td></td>
</tr>
<tr>
<td>Se</td>
<td>&gt;0.07 mg/dl</td>
<td>0.07 ± 0.01</td>
<td>0.07 ± 0.01</td>
<td>0.891</td>
<td></td>
</tr>
</tbody>
</table>

* Significant difference (p < 0.05)
locations infected the least (Table 3). One to 11 coenurus cysts per animal were found in the 40 infected goats. The coenurus cysts were surrounded by a strong, semi-opaque membrane, cloudy white in color. All cysts collected contained a single bladder worm with multiple scoleces. Table 1 shows the average and range of their volume, number of scoleces/cyst, and number of clusters/cyst. Table 4 shows the number and length of hooks found in scoleces.

No statistically significant correlation was found between position, volume of cysts, number of scoleces/cyst, or number of clusters/cyst with origin or age of animal. Also, no significant correlation was found between the number of cysts per goat and the seven morphometric measurements performed on each scolex.

On the other hand, a significant positive correlation was found between number of scoleces and volume of cysts ($b = 6.37 > 5$; R-Sq = 89.4%; P-value = 0.000), between number of clusters and volume of cysts ($b = 0.25 > 5$; R-Sq = 69.4%; P-value = 0.000), and between number of clusters and number of scoleces ($b = 25.13$; R-Sq = 79.8%; P-value = 0.000). Furthermore, cysts located in psoas muscles (Fig. 2) had on average significantly bigger volumes and higher numbers of scoleces and clusters compared to cysts located in other body parts (P-value = 0.000).

Significant differences in all seven morphometric measurements of the rostellar hooks were observed between cysts found in goats from different countries of origin. The differences for the rostellar hooks were observed between cysts found in other body parts (P-value < 0.05).

Finally, significant positive correlations were found between length of large hook (P-value = 0.021; R-Sq = 1.1%), length of handle of large hook (P-value = 0.016; R-Sq = 1.2%) and length of blade of small hook (P-value = 0.036; R-Sq = 1.0%) with age of goats. Some significant positive correlations were also observed among the seven morphometric measurements of the scoleces but which had no meaningful pattern to be listed here.

### 4. Discussion

Identifying the parasite responsible for non-cerebral coenurosis in the examined goats was outside the scope of the present study. A molecular investigation of the larvae isolated will be published in a following paper.

As mentioned in the introduction, the parasite responsible for non-cerebral coenurosis in goats was initially considered as a separate species named *Multiceps gaigeri* (Hall, 1916). Hall (1910) had already proposed the cestode parasite named *Taenia multiceps* by Leske (1780) to be re-named as *Multiceps multiceps* (Leske, 1780; Hall, 1910). Finally, Verster (1969) considered *Multiceps multiceps* along with *Multiceps gaigeri* to be synonyms of *T. multiceps*. *Taenia* species recognised today which have a coenurus stage as larvae are *T. multiceps, T. serialis* and *T. brauni* (Acha and Szysz, 2003). Verster (1969) had considered *T. brauni* as a subspecies of *T. serialis*. However, what form constitutes a separate species in the genus *Taenia* is quite a complicated task and sometimes even phylogenetic relationships for the recognised species of *Taenia* are determined differently by morphological and molecular studies (Hoberg et al., 2000; Jia et al., 2010). Meanwhile, current molecular phylogenetic studies propose the division of the genus *Taenia* to three genera: *Taenia, Hydatigera* and *Versteria* (Nakao et al., 2013).

The prevalence of non-cerebral coenurosis in the present survey (1.75%) was very different than the prevalence observed in previous surveys of goats in the same area, 0.2% by Schuster et al. (2010) and 16% by Varvasia et al. (2012). The reason for this difference is not known but the prevalence in this kind of surveys is affected by the original composition of each survey’s slaughtered animal population. Countries have different levels of livestock hygiene due to the presence of different population sizes of stray dogs, which serve as the main final hosts that spread the infection. In regard to the age, infected goats had a wider range than in the previous studies mentioned above, however the infected goats were younger than 2.5 years old. Schuster et al. (2010) suspected that age is not a limiting factor for infection although he did not report any strong evidence for such hypothesis given that the slaughtered goats are usually young.

An important observation in the present study was that coenurus cysts in the examined goats were agglomerated in a few individuals, which is indicative of overdispersion ($k < 1$). Overdispersion is the most common form of frequency distribution of parasitic communities in nature (Bush et al., 2001). Overdispersion is a phenomenon that has been previously described in cestode parasites such as *Hymenolepis citelli* in white-footed deer mouse (Wassom et al., 1986; Munger et al., 1989), *Taenia pisiformis* in dogs (Rashed et al., 1991) and deer mice (Theis and Schwab, 1992), and *Abuladzugnia guttata, Davainea nana, Hymenolepis cantaniana, Numidella numida, Octopetalum numida, Ortleppolepis multiceps* to be synonyms of *T. serialis*.

How many coenurus cysts are estimated differently to three genera: *Taenia, Hydatigera* and *Versteria* (Nakao et al., 2013).
ment in proximity. In addition, climatic variations may result in the environmental aggregation of the eggs because they are not resistant to desiccation so can survive only in soil areas that remain wet (Theis and Schwab, 1992). Finally, the presence of susceptible genotypes in the animal host population (Wassom et al., 1986) and differences in the immune competence and age resistance of individual animal hosts may contribute to overdispersion (Theis and Schwab, 1992).

No differentiating clinical signs of non-cerebral coenurosis were observed during ante-mortem clinical examination. Given the epidemiology of the disease in this area, the detection of a hard mass in thigh muscles of goats, points to a tentative diagnosis of non-cerebral coenurosis.

Infected goats had on average a significantly higher AST, but within normal range, compared to uninfected goats. The average CK was also higher in the infected group, but the difference with the uninfected was not significant. Elevated AST values are indicative of liver or muscle cell damage; while elevated CK values are indicative of muscle cell damage (Smith and Sherman, 2009). Since no liver damage was detected during carcass inspection, the elevated AST and CK values are attributed to muscle damage perhaps due to parasitism. Generally, all blood tests indicate that the animals despite their parasitism were healthy.

Cysts were located in 14 different body locations indicating that the parasite has adapted to living in tissues other than the brain. Cysts located in psoas muscles had on average significantly bigger volumes and higher numbers of scoleces and clusters compared to cysts located in other body parts. The reason for this difference may be related to the less mechanical resistance as the cysts were free to grow into the peritoneal cavity while the same time they were in contact with a specific muscle. Psoas muscle has the longest in sarcomere length, the smallest size of muscle fiber, and the lowest shear force value compared to other muscles (Sithigripong et al., 2013). It is worth to note that only the small mechanical resistance, which the proximity to the peritoneal cavity offers, is probably not able to increase the size of the cyst. Cysts located in momentum or perirenal fat were found to be of small size (4.786 ± 1.847; range 1–8 ml; n = 14).

The number of clusters and scoleces as well as the averages and ranges of the number and the lengths of large and small hooks were similar to those listed in a previous study by Schuster et al. (2010). This similarity indicates that both studies dealt with the same parasite species. The reason why especially the blades of the hooks in cysts from different origin were significantly different in length is not known, but it may be due to initial steps of allopatric speciation by geographic isolation (Huyse et al., 2005).

It is worth mentioning that the number of the rostellar hooks in the different scoleces of the same cyst was in some cases different. In these cases usually the differences in the hook number were one or two couples of hooks. Even though there are no available related data in the literature, it seems that perhaps the exact number of rostellar hooks which each parasite finally develops depends not only on its genetic characteristics but also on other extrinsic factors such as available nutrients (Sopikov, 1931).

Finally, another interesting observation was that the rate of increase of the number of scoleces was proportionally larger compared to the rate of increase in the volume of the cysts (b = 6.37 > 5) and compared to the rate of increase in the number of clusters (b = 25.13 > 1) indicating in both these cases a positive allometric growth. On the other hand, the rate of increase of the number of clusters was proportionally smaller compared to the rate of increase in the volume of the cysts indicating a negative allometric growth (b = 0.25 < 0.5). The biological significance of the observed allometries is not known. However, the propagation of the parasite directly depends on the number of scoleces and therefore, as an evolutionary adaptation, the parasite is investing its resources more on the growth of scoleces than on the growth of cyst volume or on the number of clusters.

In conclusion, non-cerebral coenurus cysts had a low prevalence and an overdispersed distribution in goats following an allometric growth. The most frequent body location of the cysts was the muscles of thigh, but the cysts in the psoas were the most developed. The only clinical abnormalities observed in the infected goats were the palpation of large single cysts in thigh muscles and the higher serum aspartate aminotransferase (AST) value.

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References


