**Introduction**

KAMENSKY (1905) discussed the systematic position of *Strongylus vasorum* Baillet, 1866 and *Ematozoa filaria cardiaca* Bossi, 1871, two species of protostrongylids from the heart and pulmonary arteries of dogs. He concluded that, according to their morphological features, these parasites should be located in a separate genus (*Angiostrongylus*), including the species *Angiostrongylus vasorum* (Baillet, 1866) and *Angiostrongylus cardicus* (BOSSI, 1871). RAILLIET & HENRY (1909), apparently unaware of the work of KAMENSKY (1905) established the genus *Haemostrongylus* for the species *S. vasorum*.

The genus *Haemostrongylus* was recognized by RAILLIET & HENRY (1909), BAYLIS & DAUBNEY (1926) and YORKE & MAPLESTONE (1926). Nevertheless LEIPER (1926) correctly noted the priority of the name *Angiostrongylus*, so that *Haemostrongylus* was reduced to a synonym. In Brazil, TRAVASSOS (1927), also unaware of the work of KAMENSKY (1905) and Leiper (1926) described *Haemostrongylus raiillieti*, a parasite of the right ven-
tricle and pulmonary arteries of the crab-eating fox *Canis azaræ* (= *Cerdocyon thous azaræ*), originated from Angra dos Reis in the state of Rio de Janeiro, Brazil.

DOUGHERTY (1946), in describing *Angiostrongylus gubernaculatus*, considered that this and five other species made up the genus: *A. vasorum* (BAILLET, 1866), the type species, *A. raillieti* (TRAVASSOS, 1927), *A. tateronae* (BAYLIS, 1928), *A. cantonensis* (Chen, 1935) and *A. ondatrae* (SCHULZ, ORLOW & KUTASS, 1933).

In 1951, Schulz created two new genera, *Rattostrongylus* and *Angiocaulus*, to receive the species *A. cantonensis* and *A. gubernaculatus*, respectively.

SKRJABIN et al. (1952) placed the *Angiostrongylus* species classified by DOUGHERTY (1946), in four genera: *Angiostrongylus* (*A. vasorum, A. raillieti, A. tateronae and A. ten*); *Rattostrongylus* (*A. cantonensis*); *Angiocaulus* (*A. gubernaculatus*) and *Rodentocaulus* (*R. ondatrae*). This classification is in accord to YAMAGUTI (1961).


GRISI (1971) made a comparative study of the material described by Travassos (1927) as *H. raillieti* and the one that was identified by de LANGENEGGER et al. (1962), as *A. vasorum*. He observed that both species possessed a gubernaculum and proposed they be classified as *Angiocaulus raillieti* (Travassos, 1927).

KINSELLA (1971) gave a key for the identification of species of *Angiostrongylus*.

**Key to the Species of *Angiostrongylus***

1. Dorsal ray expanded, as long or longer than externodorsals, parasites of shrews ................................................................. 2
   Dorsal ray reduced, shorter than externodorsals, parasites of rodents and carnivores ............................................................. 4

2. Spicules 0.330 to 0.391 mm, parasitic in bronchioles. Host:
   - *Sorex cinereus*. North America ................................................................. *A. michiganensis* ASH, 1967
   - Spicules less than 0.275 mm, parasitic in lung or lung cysts .................................................................................................................. 3

3. Spicules 0.260 mm. Hosts: *Sorex minutus, Neomys fodiens*. Europe ................................................................. *A. soricus* SOLTYS, 1954
   - Spicules 0.66 to 0.99 mm. Host: *Blarina brevicauda*. North America ................................................................. *A. blarini* OGREN, 1954

4. Spicules long, 1.0 to 1.4 mm. Hosts: *Rattus spp., Bandicota indica, Melomys littoralis*, *Homo sapiens*.
   - Hawaii, South Pacific, Asia, Australia ................................................................. *A.cantonensis* (CHEN, 1935) DOUGHERTY, 1946
   - Spicules short, less than 1.0 mm .................................................................................. 5

5. Ventoventral ray much shorter than ventrolateral ......................................................................................................................... 6
   - Ventoventral ray equal to or slightly shorter than ventrolateral ......................................................................................................... 7

6. Anterolateral ray stouter than other laterals, spicules 0.500 to 0.620 mm.
   - Lateral rays equal in width, spicules 0.330 to 0.350 mm. Hosts:
     - *Mastomys natalensis, Gerbil tatera*. Africa ................................................................. *A. sandarsae* ALICATA, 1968

7. Spicules 0.215 to 0.279 mm. Host: *Oryzomys palustris*. North America ................................................................. *A. schmidti* sp. n.
   - Spicules greater than 0.350 mm .................................................................................. 8

8. Dorsal ray short, terminating in several small digitations. Spicules 0.400 to 0.560 mm. Hosts:

9. Anus of female nearly terminal, 0.17 mm from tip of tail. Spicules 0.425 mm Host:
   - *Sciurus vulgaris*, *Eliomys quercinus*. Europe ................................................................. *A. sciuri* MERDEVENCI, 1964
   - Anus of female more than 0.50 mm from tip of tail, parasites of carnivores ................................................................. 10

10. Spicules 0.370 to 0.460 mm. Hosts: *Canis familiaris*, *Vulpes vulpes*, *Ducicynous thos*.
    - Europe, Asia, South America ................................................................. *A. vasorum* (BAILLET, 1866) KAMENSKY, 1905
    - Spicules greater than 0.500 mm .................................................................................. 11

11. Vulva to tip of tail 0.170 to 0.210 mm, spicules 0.510 to 0.555 mm. Hosts:
    - Felis sylvestris, Europe ................................................................. *A. chabaudi* BIOCCA, 1957
    - Vulva to tip of tail 0.205 to 0.250 mm, spicules 0.510 to 0.560 mm. Hosts:
      - *Taxidea taxus, Mephilis mephilis*. North America ................................................................. *A. gubernaculatus* DOUGHERTY, 1946

*Revue Méd. Vét.*, 2003, **154**, 1, 9-16
Based upon the morphology of the bursal rays, UBELAKER (1986) considered six genera of angiostrongylids: Angiostrongylus KAMENSKY, 1905 (syn. of Haemostrongylus Railliet & Henry, 1907); Parasangyulus BAYLIS, 1928 (syn. of Pulmonema CHEN, 1935; Rastrostrongylus SCHULZ, 1951; Morerastrongylus CHABAUD, 1972; Chabaudstrongylus Kontrimovich & DELAMORE, 1979); Angiocaulus SCHULZ, ORLOW & KUTASS, 1933 (syn. of Cardisonema YAMAGUTI, 1941); Rodentocaulus SCHULZ, ORLOW & KUTASS, 1933; Gallegostrongylus MAS-COMA, 1977 (syn. of Thastrongylus okyayashi, KAMIIYA & BHAIBULAYA, 1979) and Steinkostrongylus DROZDZ, 1970.

The purpose of this study was to make a review of the genera Angiostrongylus and a redescription of the species A. vasorum.

Materials and methods
Snails of the species Biomphalaria glabrata reared in the laboratory were used to obtain infective larvae of A. vasorum. Ten dogs, also reared in the laboratory, were orally infected with approximately 50 L3 of A. vasorum per kg, as described by COSTA & TAFURI (1997).

COLLECTION OF NEMATODES FOR MORPHOLOGICAL STUDIES:
Parasite were collected from heart, pulmonary arteries and their branches and transferred to Pyrex dishes filled with 0.85% saline. The recovered nematodes were fixed in 5% formalin or with AFA (ethanol 30%, formalin 9%, acetic acid 1.5% and distilled water 59.5%) at approximately 80°C and cleared in Aman’s lactophenol for microscopy studies. Some worms were fixed in 3% glutaraldehyde and prepared for scanning electron microscopy (GUIMARAES & CALDEIRA, 1997). Other specimens were examined without any preparation, after being stored at 5°C for 24 h, so as to get a better observation of their morphological structures.

Results
REDESCRIPTION:

Angiostrongylus vasorum (BAILLET, 1866) KAMENSKY, 1905.

Synonyms:
Strongylus vasorum BAILLET, 1866
Ematozoa filaria cardiaca BOSSI, 1871;
Haemonchus vasorum (Baillet,1866) SLUITER & SWELLENGREBEL, 1912;
Haemostrongylus vasorum (BAILLET, 1866) Railliet & Henry, 1907;
Haemostrongylus raiillieti TRAVASSOS, 1927; Angiostrongylus raiillieti (TRAVASSOS, 1927) DOUGHERT, 1946;
Angiocaulus raiillieti (TRAVASSOS, 1927) GRISI, 1971.

Host: Canis familiaris, L.
Sites of infection: atrium, right auricle and branches of the pulmonary artery.

Nematodes with slender and elongated body, attenuated at extremities. Cuticle of cephalic extremity slightly dilated. Buccal aperture small, circular, surrounded by six small papillae (Fig. 1), as well as four radial channels, each one enclosing a double papilla (lateral papillae). Amphids on each side, between the channels. Nerve ring situated near the start of the last third of the esophagus. Excretory pore situated ventrally below the junction of the esophagus with the intestine, which is somewhat intertwined with the genital tube. Intestinal diameter clearly wider than the oesophageal one (Fig. 2).

Males: smaller and more slender than females; mean length 12.905 mm and mean width 0.240mm. Esophagus 0.250 mm long, 0.025 mm wide anteriorly and 0.039 mm at posterior end. Anterior extremity slightly recurved ventrally. Excretory pore distinct, located just after the termination of the esophagus at 0.373 mm from the anterior extremity; nerve ring situated at 0.191mm from this extremity.

Copulatory bursa very short (Fig. 3 and 4) lacking a median lobe but with two identical and symmetrical lateral lobes. Compared to other protostrongylids, bursal rays well developed; ventral (ventro-ventral and ventro-lateral) rays originating from a common trunk and fused to it for first two thirds, extending until almost the edge of the lobe, the ventro-ventral ray being slightly shorter than the ventro-lateral; lateral rays also originating from a common trunk but anterior lateral ray becoming divergent from the first third of its length onwards, while the medio-lateral and posterior rays continue fused, separating from the main trunk in the final third. The lateral dorsal rays originate separately from the dorsal median that remains in the median position, very much shorter than the other rays, with two subequal digitations, a papilla sometimes occurring between them. Spicules long and strong, yellowish-chestnut, strongly sclerotized and transversely striated; subequal, measuring approximately 0.466 mm. Each one possesses, on the internal surface, an external membrane, weakly sclerotized and finely striated. Distal extremity trifurcate with very small furcae and intertwined with the membrane. Gubernaculum weakly sclerotized, navicular and measuring 0.041 mm long; difficult to see (Fig. 5). Cloacal aperture simple and lacking processes. The measurements of 12 male examples are presented in Table I, including means, standard deviations, total and median widths.

Females: measuring on average 15.578 mm long by 0.268mm wide. In recently collected examples the milky colored genital ducts can be seen intertwined helicoidally around the reddish intestine. This anatomical particularity is easily observed due to the fine, transparent cuticle. Buccal opening continuing directly with the esophagus, which measures 0.282 mm long with an anterior width of 0.32 mm and posterior width of 0.046 mm. Excretory pore distinct, located

Revue Méd. Vét., 2003, 154, 1, 9-16
TABLE I. — Measurements taken of 12 males and 10 females of *Angiostrongylus vasorum* (in mm).

<table>
<thead>
<tr>
<th>Parameters measured</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Amplitude</td>
</tr>
<tr>
<td>Width</td>
<td>0.243</td>
<td>0.216/0.298</td>
</tr>
<tr>
<td>Anterior width</td>
<td>0.025</td>
<td>0.019/0.033</td>
</tr>
<tr>
<td>Posterior width</td>
<td>0.039</td>
<td>0.033/0.053</td>
</tr>
<tr>
<td>Distance nerve ring/anterior end</td>
<td>0.191</td>
<td>0.181/0.213</td>
</tr>
<tr>
<td>Distance excretory pore/anterior end</td>
<td>0.373</td>
<td>0.289/0.422</td>
</tr>
<tr>
<td>Distance vulva/anus</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Distance anus/posterior end</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Distance vulva/posterior end</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Length of spicules</td>
<td>0.466</td>
<td>0.410/0.485</td>
</tr>
<tr>
<td>Length of gubernaculum</td>
<td>0.041</td>
<td>0.039/0.043</td>
</tr>
</tbody>
</table>

**Figure 1.** — *Angiostrongylus vasorum*: scanning electron micrographies: 1 - Buccal opening; 2 - Copulatory bursa (dorsal view); 3 - Cloacal opening; 4 - Posterior extremity of female.
after a termination of the esophagus, and distad 0.403 mm of the anterior extremity. Nerve ring situated at 0.215 mm from the same extremity. Prodelphs with long cylindrical ovaries, one of them usually reaching the level of the nerve ring. Oviducts a continuation of the ovaries and themselves connected to the uterus, usually replete with ovocytes. Vagina well developed, communicating anteriorly with the only portion of the uterus and opening to the exterior by the vulva, situated anteriorly and at 0.141 mm from the anus. Cauda recurved and 0.067 mm long (Fig. 8). The measurements of 10 females are presented in Table I.

Discussion

When compared to those quoted by other authors (TRAVASSOS, 1927; NEVEU-LEMAIRE, 1936; LANGENEGGER et al., 1962; ROSEN et al., 1970; GRISI, 1971; LIMA et al., 1985) the mean lengths of the helminths examined in the present study show similarities and sometimes slight variations. ROSEN et al. (1970), observed that these variations could be related to the intervals after infection. Male collected at 50 and 169 days measured respectively 11.04-13.20 mm (mean 12.38) and 13.67-15.96 mm (mean 14.7), while females measured 13.95-15.96 mm (mean 14.87) and 18.56 - 21.30mm (mean 19.90). Other
measurements such as length of spicules, esophagus etc. (Table I) are practically identical to those observed by other authors such as ROSEN et al. (1970) and GUILHON & CENS (1973).

Based on the morphology of the bursal rays, UBELAKER (1986) also recognizes the genus Rodentocaulus Schulz, ORLOW & KUTASS, 1933 and points out that the following species may be considered as valid: Angiostrongylus parasites of carnivores, Angiocaulus of mustelids; Gallegostrongylus of gerbilids and murids; and Stefakostrongylus of insectivores. He affirms that the angiostrongylids should be placed in five genera and adds to this group the genus Rodentocaulus, whose type species R. ondatrae had been transferred to Angiostrongylus by DOUGHERTY (1946).

However SKRJABIN et al. (1961) had already returned A. ondatrae SCHULZ, ORLOW & KUTASS, 1933 to the genus Rodentocaulus, a position accepted by DROZDZ (1970), CHABAUD (1972), ANDERSON (1976) and KONTRIMA VICHUS & DELYAMURE (1979).

Diverse considerations should be made in relation to the genus Angiocaulus SCHULZ (1951), taking into account the classification of YAMAGUTI (1961) maintained by UBELAKER (1986). Careful scrutiny should be made on the diverse descriptions and comments made on the genera Angiostrongylus and Angiocaulus, by the following authors: TRAVASSOS (1927), DOUGHERTY (1946), ASH (1967), GRISI (1971), GUILHON & CENS (1973), LIMA et al. (1985) and UBELAKER (1986).

Comparative analysis of the descriptions made by the authors, added to the descriptions of the present study, shows the existence of great similarities that lead us to agree with CHABAUD (1972), DROZDZ (1970), ANDERSON (1978) and OHBAYASHI (1988), who considered Angiocaulus to be a synonym of Angiostrongylus.

SCHULZ (1951) transferred the species A. cantonensis DOUGHERTY, 1946 to the genus Rattostrongylus SCHULZ, 1951, of which it was the type species. In the same paper, A. gubernaculatus was transferred to the genus Angiocaulus SCHULZ (1951), of which it would also be the type species. The two new genera were maintained by YAMAGUTI (1961) who simply agree with the identification key for the Angiostrongilinae provided by SKRJABIN et al. (1952), itself based on the SCHULZ (1951) study.

Comparison of the copulatory bursa of A. vasorum, the type species of the genus, with that of A. cantonensis reveals only a slight difference in the dorsal ray. The terminal part of the dorsal ray in A. vasorum forms an inverted shallow U, while in A. cantonensis it ends in three minuscule papillae, rarely only two, also forming an indistinct inverted U. From examination of illustrations of other Angiostrongylus spp. it may be verified that the dorsal ray is not split by a deep incision. ASH (1967) preferred to retain A. gubernaculatus in the genus Angiocaulus, because of the presence of the gubernaculum. Our results are in agreement with GUILHON & CENS (1973) observations on Angiostrongylus vasorum (Figs. 3 & 4).
According to UBELAKER (1986) and CHAUBAUD (1972), four characters are more important than the length of the spicules. Three of these are related to the bursa and one to the site of adult worms. These authors consider that the lungs and intestinal tract constitute a distinct substrate, different to that where there is direct survival in tissue as the members of the genus Stefankostrongylus. UBELAKER et al. (1981) showed that Angiostrongylus costaricensis (MOREIRA & CISPEDES, 1971) may survive in the vessels of the lung or the intestine (caecum) depending on the route of penetration in the organism or as a result of superinfection.

In addition to the gubernaculum, the median digit described by GRISI (1971) in the dorsal ray would be a character that could be used to differentiate A. raillieti. This median digit was described by TRA VASSOS (1927) as a papilla. These papillae were also observed by LIMA et al. (1985). It is worth remembering that ASH (1967) commented that there are usually three, rarely two papillae in the same position in A. cantonensis. Variation in the number or presence of papillae on the dorsal ray could certainly be overlooked. It should be recalled that the gubernaculum, much more prominent and large on the dorsal ray could certainly be overlooked. It should be pointed out that GRISI (1992) remembered with a key to the species of Angiostrongylus schmidti (also with a gubernaculum).

ANDERSON (1978), remembers that several angiostrongylid species are small and difficult to orient to allow examination of the bursa, as well as frequently being subject to distortions after fixation, increasing the possibilities of incorrect interpretations of observations. It is interesting to note that using recently collected material after refrigeration facilitated greatly the observation of the bursal structures.

Conclusions

We present a new description of A. vasorum followed by scanning electron micrographs and optical microscope drawings. The use of freshly collected specimens after refrigeration made it easier to observe the bursal structures. This critical analysis of the literature on the genera Angiostrongylus and Angiocaulus enables us to take the position that the latter should be considered, if not a nomem nudum, then at least a synonym of Angiostrongylus.

References


