Trends in Parasitology

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Review

Felid Lungworms and Heartworms in Italy: More Questions than Answers?

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Nematodes infecting the cardiorespiratory system of cats have recently stimulated high scientific interest. Over the past few years, different aspects of these parasites have been clarified and various issues elucidated. This increased knowledge has improved awareness on this topic but, at the same time, some dilemmas have not been solved and new questions have been raised. In this review, we underline and discuss current knowledge of, and new doubts relating to, feline lungworms and heartworms, with the aim of stimulating new studies to fill gaps of basic (i.e., epidemiology and biology) and applied (i.e., clinical aspects) knowledge of the old and new parasites affecting the cardiorespiratory system of cats.

Felid Extra-Intestinal Nematodes: An Intricate Puzzle

Until recently, the 'cat lungworm' *Aelurostrongylus abstrusus* and, to a lesser extent, *Capillaria aerophila* were considered the only important lungworms affecting the domestic cat (*Felis silvestris catus*) worldwide [1,2]. However, over the past few years, other extra-intestinal nematodes have been found in domestic cats. *Troglostrongylus brevior*, first recorded in 1949 in wild felids [3], was described few years later in a European wildcat (*Felis silvestris silvestris*) and in a feral cat of unknown origin caught in central Italy [4]. This lungworm was not described again until 2010–2012, when single descriptions in domestic cats from Ibiza [5] and Sicily [6] resulted in intense scientific attention. As a consequence, the presence of *T. brevior* has been unveiled in domestic cats inhabiting European islands, and in Apennine areas of central and southern Italy [7–11].

Therefore, in 2013, new findings on felid lungworms were discussed and debated [2,12,13], with a particular focus on the significance of cat respiratory parasites. Since then, although new studies have provided answers, old dilemmas persist and new questions have been raised. In fact, paradoxically, this increase in knowledge and awareness has complicated an already intricate puzzle. A key example is given by the recent descriptions of nematodes, identified as *Angiostrongylus chabaudi*, from the pulmonary arteries of two domestic cats. This parasite was described for the first time during the 20th century in European wildcats from a region of central Italy [14]. It remained almost unknown until the past few months, when it was isolated in a domestic cat from Sardinia, Italy [15] and in a domestic cat [16] and a wildcat [17] from mountainous central Italy. Similarly, the respiratory metastrongyloid *Oslerus rostratus* was, until recently, recorded in domestic cats very rarely and only in confined geographic areas [2]. However, in 2014, this nematode was described from two single cats from Italian islands [18,19]. By contrast, following the single report from Sicily in 2012 [6], *Troglostrongylus subcrenatus* has not been described again.

While metastrongyloids have an indirect life cycle, with terrestrial mollusks acting as intermediate hosts, *C. aerophila* has a direct biological cycle and earthworms have been suggested as facultative intermediate or paratenic hosts [2].

Trends

Some nematodes affecting the cardiorespiratory system of cats are of increasing importance for their geographic expansion in both endemic and nonendemic regions, and their potential impact in feline clinical practice.

Until a few years ago, the cat lungworm *Aelurostrongylus abstrusus* (Nematoda, Metastrongyloidea) and, to a lesser extent, *Capillaria aerophila* (Nematoda, Trichurida), were considered the sole nematodes affecting the lungs of cats.

The canine heartworm *Dirofilaria immitis* was considered the only nematode able to affect the heart and pulmonary vessels of cats, although rarely.

Over the past few years, other little-known nematodes (e.g., *Troglostrongylus brevior* and *Angiostrongylus chabaudi*) have been found in the cardiorespiratory system of domestic cats, either for the first time or following a long gap since the previous record.

These new reports have improved our knowledge of feline respiratory system nematodes, but some questions remain and new dilemmas have emerged.

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Given this continuous changing background of knowledge, we discuss here the recent advances in our knowledge of the cardiorespiratory parasites of cats, highlighting questions that remain and those that have arisen from recent studies.

Lungworms: *A. abstrusus* or *T. brevior*?

It is unclear whether past reports of *T. brevior* were erroneously attributed to *A. abstrusus* due to confusion between the diagnostic stages of *A. abstrusus* and *T. brevior* (Box 1) and/or a lack of awareness of lungworms other than *A. abstrusus* [2,6,12]. However, the hypothesis of a frequent misdiagnosis [6,12] was considered unlikely, based on clinical and pathological

Box 1. Diagnosis: What is Required?

Serological tests, although promising only for aelurostrongylosis, are not available in current clinical practice [61]. The diagnosis of these infections relies mainly on the detection of parasite elements in the feces of infected cats. While the characteristics of *Capillaria aerophila* eggs have been elucidated [62], features of the metastrongyloid L1 (i.e., the diagnostic stage) have raised doubts on the reliability of past diagnoses of respiratory parasitoses in cats [2,12,13]. Careful appraisal of the position of the oral opening, tail aspect (Figure I), body length, and anal opening enables one to discriminate between L1 of *Aelurostrongylus abstrusus* and *Troglostrongylus brevior* (and *Oslerus rostratus*) [34]. Nonetheless, the length of feline metastrongyloid L1 is still unresolved. L1s of *A. abstrusus* with a length more similar to that of *Troglostrongylus* spp. have been occasionally described [5,63]. Furthermore, it has been stated [34] that *O. rostratus* larvae may grow during their intestinal passage, because L1 found in respiratory airways appear smaller than those recovered from feces [3,48]. These controversial results require additional studies to draw sound conclusions on the potential larval growth of metastrongyloids after egg hatching and to ultimately establish the morphometry of *O. rostratus* and *A. abstrusus* L1. No definitive data are available on *Troglostrongylus subcrenatus* L1 in domestic cats, because no other cases have been published since that of the single infected kitten from Sicily in 2012 [6]. L1 of *A. chabaudi* have never been described and doubts remain over the establishment of patent infections in domestic cats.

Genetic tools may overcome gaps in the microscopic diagnosis of felid extra-intestinal infections. A DNA-based assay specific for *C. aerophila* enables its molecular identification in feline (and canine) fecal samples, even in mixed infections with other lungworms [64]. New PCRs have proved to be effective in detecting the DNA of *A. abstrusus* and *T. brevior* in field-collected samples [8,65]. These assays may be used on feces and pharyngeal swabs, thus presenting important advantages in clinical settings [8,65]. Recently, a triplex semi-nested PCR validated for the simultaneous discrimination of *A. abstrusus*, *T. brevior*, and *A. chabaudi* showed promise for basic and applied studies on these nematodes [66]. A molecular test specific for *O. rostratus* is still awaited.

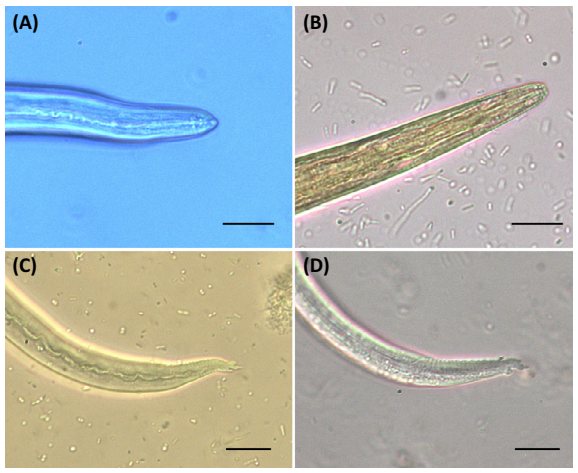

Figure I. Morphological Aspects of *Troglostrongylus brevior* and *Aelurostrongylus abstrusus* L1. (A) Anterior end of *T. brevior* L1, showing the pointed head and subterminal oral opening. (B) Anterior end of *A. abstrusus* L1, showing the rounded extremity and terminal oral opening. (C) Tail of *T. brevior* L1, showing the deep dorsal incisure and the shallower ventral incisure. (D) Tail of *A. abstrusus* L1, showing its S shape, distinct knob-like or small finger- like projections at the tip of cuticular spines, deep dorsal incisure, and ventral incisure. Scale bars = 20 μm.