DIAGNOSIS AND MANAGEMENT OF LUNGWORM INFECTIONS IN CATS
Cornerstones, dilemmas and new avenues

Donato Traversa and Angela Di Cesare

Lungworms of cats

Traditionally, feline lungworms have been reported to be Aelurostrongylus abstrusus (Nematoda, Metastrongyloidea, Angiostrongylidae) and Capillaria aerophila (syn Eucoleus aerophilus) (Nematoda, Trichocephalida, Trichuridae). Of these, A. abstrusus (ie, the ‘cat lungworm’) has long been regarded as the most significant respiratory parasite of domestic cats (Felis silvestris catus) in terms of worldwide geographic distribution and clinical importance. The adult stages of A. abstrusus (length ~5–12 mm, width ~54–80 µm) reside in nodules within the bronchi-oles, alveolar ducts and alve-o loli of infected hosts.

Conversely, C. aerophila has been little recognised as a significant pathogen until recently. This nematode infects the lungs of domestic and wild carnivores and, sometimes, people. The adult stages (length ~20–30 mm) are slender (width ~60–180 µm), whitish and filamentous, and live beneath the epithelium of the tra-chea and bronchi. This nematode has a direct life cycle (Figure 1). After mating, the females release eggs that are coughed, ingested and passed in the faeces of the infected animal. In the environment, they reach infectivity in 1–2 months. Earthworms have been hypothesised to act as facultative intermediate or paratenic hosts, but this biological feature has not been conclusively established. Animals become infected by ingesting lar-vated eggs present in the environment or, potentially, infected earthworms.

It is now known that A. abstrusus and C. aerophila are not the

Clinical signs of lungworm infection can be identical to those caused by bronchial disease/asthma, leading to potential misdiagnosis.

Practical relevance: Respiratory parasites infecting domestic cats are attracting increased attention in feline clinical practice. In addition to the most commonly recognised ‘cat lungworm’ Aelurostrongylus abstrusus, Troglostrongylus brevior and Capillaria aerophila are now considered important pathogens of the respiratory tract of cats.

Global importance: These parasites are being increasingly diagnosed in several regions of the world and a continuous update on epidemiological changes and advances in diagnosis and control is of practical importance.

Aims: This article reviews current knowledge of lungworms affecting cats, with a special focus on recent insights into diagnosis and management of the diseases they cause. The article also explores some potential new avenues for control of feline parasitic respiratory diseases, and highlights some key areas requiring further research.

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DOI: 10.1177/1098612X15623113 © The Author(s) 2016

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only lungworms to infect domestic cats. The genus *Troglostrongylus* (Nematoda, Metastrongylidea, Crenosomatidae), which includes four species of lungworms, mostly reported from wildlife (eg, leopard, African wildcat), has also now been identified in domestic cats. *Troglostrongylus brevior*, first described in *Felis silvestris lybica*, the African wildcat, and in *Felis chaus*, the Jungle cat, has recently been reported. Adult worms of *T. brevior* vary from ~5–13 mm in length and ~294–430 µm in width, and inhabit the bronchi and bronchioles of infected hosts.

*Figure 1* The adult stages of *Capillaria aerophila* live under the epithelium of the trachea and bronchi. After mating, the females release eggs that are coughed, ingested and passed in the faeces of the infected animal. In the environment, they mature and become infective. Earthworms have been hypothesised to act as facultative intermediate or paratenic hosts. Animals become infected by ingesting environmental larvated eggs or, potentially, infected earthworms.

*Figure 2* The adult stages of these nematodes live in the respiratory system of the definitive host: bronchioles, alveolar ducts and alveoli (*Aelurostrongylus abstrusus*) or bronchi and bronchioles (*Troglostrongylus brevior*). The females release eggs that develop within the parenchyma and, after hatching, first stage larvae (L1s) pass up the respiratory escalator, are swallowed and excreted via the faeces, and reach the environment. L1s continue their development in intermediate hosts (slugs and snails), in which they reach the third, infective, larval stage (L3), which is infective for cats. Cats become infected by ingesting the mollusc or, more frequently, paratenic hosts (rodents, frogs, lizards, snakes, birds). Thereafter, L3s migrate to the lungs via the haemolymphatic vessels and evolve to adulthood in the respiratory system.
New paradigms for a changing epidemiology

It is speculated that the geographic range of lungworms infecting cats is possibly expanding. Global warming, movements of animals from endemic to free regions, changing vector phenology, and modification in wildlife habitat and populations may be involved. Alternatively, heightened awareness may have led to an increase in documented clinical diagnoses of previously unknown or underestimated nematodes.

**A abstrusus**

*A abstrusus* is distributed worldwide and may infect all cats regardless of their habitat, lifestyle, sex and breed. It is present in nearly every European country, and has been described in Australia and the Americas, as well as in some reports from Asia and Africa. Owned animals and cats living indoors or with few chances to access the environment are at less risk of *A abstrusus* infection. However, infection should not be ruled out in household cats. Young animals, with a less efficient immune system, and adult and old cats, with better hunting ability and a cumulative greater risk of exposure, may be infected by *A abstrusus*.

**C aerophila**

*C aerophila* has long been found in wildlife. In Europe it has occasionally been reported in companion animals, while for many years up to 5% of feral cats in Australia have consistently been found to be infected with *C aerophila*. Over the past couple of decades there has been an increase in the number of clinical descriptions, and epidemiological studies have documented the occurrence of *C aerophila* in cats from different countries, and in humans as well. In some European countries it is likely that wildlife may influence the dispersion of lung capillariosis in cats, as suggested by recent genetic studies that have indicated that *C aerophila* populations co-infect pets and wildlife in the same areas.

**T brevior**

Nematodes of the genus *Troglostrongylus* have historically been regarded as parasites of wild felids, but infections in domestic cats are being increasingly reported, mostly in young animals. The first report of troglostrongylosis in a domestic host was from the last century when a feral cat was found to harbour *T brevior*. Since 2010, however, *T brevior* has been described in domestic cats from several European islands (Ibiza, Sicily, Sardinia, Crete), and in central and southern Apennine regions of Italy.

Wild animals such as the European wildcat play a role as spreaders of *T brevior* in areas where wildcats and domestic cats coexist.

This increased detection rate in domestic cats has raised questions regarding the origin and actual distribution of *T brevior* in felid populations. It is not known whether: (i) *T brevior* infects *F s catus* more frequently than previously thought and that historically it has been mistaken for *A abstrusus*; (ii) recent reports reflect increased infection in domestic felids only in particular areas; and/or (iii) some epidemiological drivers have nurtured a spillover of lungworms from wildlife to *F s catus*.

Reduction of woodland habitat drives wild animals into new hospitable environments, such as suburbs and cities, in search of anthropogenic food sources. These movements increase the contact between wildlife and pets and contribute to the spread of parasites harboured by wildlife. Wild animals such as the European wildcat (*F felis silvestris silvestris*), in which *T brevior* has been found, play a role as spreaders of the parasite in those areas where wildcats and domestic cats live in sympatry. Indeed, *T brevior* has been mostly described thus far in cats living in areas of Italy and Greece where wildcat populations are present. Additionally, in domestic cats, *T brevior* is often found in association with *A abstrusus*.

A recent retrospective study demonstrated negligible occurrence of *Troglostrongylus* species in domestic cats living in sub-Apennine territories of central Italy during the years 2002–2013. The high presence of *T brevior* in wildcats originating from the same geographic areas, along with other findings, ultimately confirm the role of the European wildcat as a natural host of *T brevior*. Other data collected in 2014/2015 have shown that the prevalence of monospecific infections by *T brevior* or *A abstrusus* in domestic cat populations living in regions of the sub-Apennine territories of central Italy is similar. These recent studies suggest that in the past few years some epidemiological and biological drivers might have nurtured bridging infections by *T brevior* between wildlife and *F s catus*, and that the nematode is now expanding its host range to include domestic hosts.

This assumption is corroborated by recent findings pertaining to the closely related metagastrostrongylid *Angiostrongylus vasorum*, which affects canids in Europe. The high occurrence of this mollusc-borne nematode in...
Advances in understanding of feline lungworm disease

Possible influence of global warming

Another possible driver influencing current changes in feline lungworm epidemiology is global warming. Temperature, moisture and water availability affect the development and survival of molluscs. The development of nematode larvae in snails and slugs is also known to be influenced by temperature changes. For instance, the higher the average temperature, the higher the rate of larval development of *A abstrusus* in *Helix aspersa* (Figure 3), the Mediterranean edible snail,40 *H aspersa*, one of the most widely distributed land snails in the world,41 has been deliberately or accidentally imported into different regions and is widely regarded as a pest outside its native Mediterranean range.42 This mollusc is one of the most important intermediate hosts of *A abstrusus* and *T brevior*, and it is plausible that it has contributed (and is contributing) to the expansion of feline metastrongyloids in European countries.43 Changes in geographic distribution influenced by global warming have been predicted for *A vasorum* via a climatic-based model.44 No similar information is available for *A abstrusus* or *T brevior*; however, with similar biological cycles, the same factors involved in the expansion of canine angiostrongylosis would likely also affect feline lungworms. Further studies in this field are warranted.

**Clinical presentation**

*A abstrusus* infection

Adult parasites, production of eggs and larval migration elicit a mild to heavy granulomatous or mixed inflammatory response in *A abstrusus*-infected cats.45,46 Clinical signs depend on factors such as the worm burden and health status, age and immune response of the animal.47,48 Cats may be subclinically infected or show mild to severe disease, including, occasionally, fatal pneumonia. When signs are mild (eg, in adult cats and/or in the presence of low worm burdens), aelurostrongylosis may be self-limiting with respiratory signs spontaneously resolving within weeks.11,47 The most frequent signs are mild to intense coughing, wheezing, sneezing, nasal discharge, dyspnoea and tachypnoea.13,49 Generalised signs such as lethargy and weight loss have also been described.50,51 Severe signs such as open-mouth abdominal breathing (Figure 4), tachycardia and even death may occur in young, debilitated and/or immunosuppressed cats.52 Aelurostrongylosis has furthermore been implicated in cases of anaesthetic-associated deaths, likely due to the decreased surface area for gas exchange and a combination of impaired lung perfusion and ventilation, hypoxia and systemic hypotension, culminating in cardiovascular collapse.53

*C aerophila* infection

Cats with a *C aerophila* parasitosis may either have a subclinical infection or may display respiratory distress. Adult parasites induce lesions in the trachea and lung parenchyma, leading to increased bronchoesacular breath sounds, sneezing, wheezing and a dry cough that can become productive when bacterial complications intervene.54

*T brevior* infection

Kittens and young cats seem to be more susceptible than adult animals to *T brevior* infection. This may be due to a vertical route of transmission, which does not occur in adult animals, or to the body size of adult parasites and their localisation in the bronchi and bronchioles. Respiratory signs include a severe cough, dyspnoea and nasal discharge. Infection may lead to fatal respiratory failure in kittens despite appropriate anthelmintic treatment.55,10,23,26 Importantly, a case of irreversible (despite anthelmintic treatment) pulmonary hypertension in a kitten with troglostrongylosis has recently been described.54 No other reports of pulmonary hypertension in lungworm-infected cats have been documented, with the exception of an *A abstrusus*-infected cat from the Netherlands; in this case, the hypertension was reversible and resolved after repeated parasiticide treatment.56 Self-limiting or subclinical infections occur in older cats.5 The severity of clinical signs in infected cats probably depends on the extent of pulmonary oedema, congestion, haemorrhage, hepatisation and lobular phlogosis of the infected lungs.28

Figure 3 The Mediterranean land snail *Helix aspersa* may be contributing to the expansion of feline metastrongyloids

Figure 4 Open-mouth breathing in a cat infected with *Aelurostrongylus abstrusus*
Diagnostic features

Respiratory parasites of cats are often challenging to diagnose clinically because other conditions present with similar signs. Differential diagnoses include bacterial infections, other parasitic infections such as pulmonary toxoplasmosis, respiratory mycoses, feline bronchial disease/asthma, airway foreign bodies and pulmonary tumours.11,16 Signs caused by *A. abstrusus* can be identical to those associated with feline bronchial disease/asthma.16 Furthermore, treatment for bronchial disease/asthma with corticosteroids and bronchodilators may produce a clinical recovery in cats with respiratory parasitoses; thus veterinarians have no reason to suspect a misdiagnosis.3,16 There is no evidence at the moment, but it is likely that similar confusion might arise in cats infected with *T. brevior*.

Features of radiographic examinations are not pathognomonic for aelurostrongylosis.57,58 The most common findings in cats infected by *A. abstrusus* and *T. brevior* are an alveolar pattern followed by bronchial and interstitial patterns, bronchial wall thickening and increased interstitial opacity (Figure 5), depending on the worm burden and the chronicity of infection.

Assays for the serological diagnosis of feline lungworms are still awaited. A recently developed immunofluorescence antibody test (IFAT) able to detect antibodies against *A. abstrusus* in sera from both experimentally and naturally infected cats showed promising sensitivity and specificity.59 However, currently, definitive ante-mortem diagnosis of respiratory parasitosis can be achieved only with copromicroscopic or airway wash examinations that reveal L1s of *A. abstrusus* and *T. brevior*, and eggs of *C. aerophila*.

Direct faecal smears and classical sedimentation and flotation methods are unreliable for diagnosing metastrongyloid infections, because of the unpredictable presence of L1s, inadequate sample size, low sensitivity and larval osmotic damage (Figure 6) due to the high specific gravity concentrated.
The gold standard faecal test to diagnose feline aelurostrongylosis and troglodrstrongylosis is the Baermann migration method. However, it requires 12–48 h before larvae can be found and specific skills in discriminating between L1s. In addition, repeated examinations are necessary to avoid false negative samples due to prepatent infections or intermittent eliminating and non-eliminating shedding cycles. An accurate morphological and morphometric appraisal of L1s is necessary to achieve a species-specific diagnosis but microscopic differentiation between A abstrusus and T brevior (Figure 7) is often difficult due to overlapping morphological features and individual variations in some characteristics. The lengths of A abstrusus and T brevior L1s are ~360–415 µm and ~300–357 µm, respectively. How -

ever, A abstrusus L1s as short as ~300 µm have been reported in cases confirmed with histological and genetic characterisation. Thus, L1s of the two species should also be differentiated based on head and tail features.

The head of A abstrusus L1s is rounded and has a terminal oral opening, while the tail is kinked (S-shaped) with distinct knob-like or small finger-like projections at the tip of cuticular spines (Figure 8). L1s of T brevior have a pointed anterior extremity and a subterminal (dorsal) oral opening, while the tail gradually tapers towards the extremity, and possesses a deep dorsal incisure and a shallower ventral incisure near the tip (Figure 8).

L1s of A abstrusus (and presumably of T brevior, although no evidence is published) can be detected in other samples such as transtracheal aspirates, tracheal swabs, bronchoalveolar lavage fluid and pleural effusions.

Given potential overlap in A abstrusus and T brevior L1 length, the two species should be differentiated based on head and tail features.

Figure 7 First stage larvae of (a) Aelurostrongylus abstrusus and (b) Troglodrstrongylus brevior

Figure 8 (a,b) First stage larva of Aelurostrongylus abstrusus: (a) magnification of the anterior end, showing a rounded extremity and a terminal oral opening; (b) magnification of the tail, which is kinked, with distinct knob-like or small finger-like projections at the tip of cuticular spines. Note the dorsal incisure (bold arrow) and the anal opening (light arrow). (c,d) First stage larva of Troglodrstrongylus brevior: (c) magnification of the anterior end, showing a pointed head and a subterminal oral opening; (d) magnification of the tail, showing the presence of a deeper dorsal incisure (bold arrow) and a shallower ventral incisure. Note the anal opening (light arrow). Scale bar = 20 µm
However, sampling from the respiratory tract requires sedation or anaesthesia and these procedures may fail to detect larvae due to absence of significant pulmonary tissue involvement, limited numbers of L1s, prepatent infection or poor sample recovery.11

Lung capillariosis is diagnosed by identification of typical eggs on conventional copromicroscopy. Eggs of *C aerophila* (Figure 9) have a net-like outer shell, measure ~60–65 x ~25–40 µm, are barrel shaped, and have asymmetrical bipolar plugs with no thickening at the base.68 These ova should be differentiated from those of feline whipworms or other capillariids. There is a paucity of data on feline *Trichuris* species, as they have been recorded extremely rarely and only in limited geographical areas.4,11 Their eggs reportedly have symmetrical and ringed plugs and differ in size compared with those of *C aerophila*. Faecal examination may be complicated by the fact that cats may shed trichurid eggs laid by other capillariids or by parasites of ingested prey.11

Differential characteristics of the most important metastrongyloid L1s and trichurid eggs that can be found in cat faecal samples are described in Table 1.

![Figure 9](https://jfm.sagepub.com/content/jfm/13/8/720/F1.large.jpg) **Figure 9** Egg of *Capillaria aerophila*, showing the typical barrel shape, asymmetry of polar plugs and absence of ring thickening at the base of the plug. Scale bar = 10 µm

### Table 1 Differential features of metastrongyloid larvae and trichurid eggs that can be found in feline faecal samples

<table>
<thead>
<tr>
<th>Nematode</th>
<th>Length (µm)</th>
<th>Width (µm)</th>
<th>Head</th>
<th>Tail</th>
<th>Plugs</th>
<th>Shell</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First stage larvae</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Aelurostrongylus abstrusus</em></td>
<td>360–415*</td>
<td>18–19</td>
<td>Rounded, terminal oral opening</td>
<td>Kinked (S-shaped)</td>
<td>Knob-like or small finger-like projections at tip of cuticular spines</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><em>Troglostrongylus brevior</em></td>
<td>300–357</td>
<td>16–19</td>
<td>Pointed, subterminal (dorsal) oral opening</td>
<td>Gradually tapered to the extremity</td>
<td>Deep dorsal incisure and shallower ventral incisure#</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><em>Troglostrongylus subcrenatus</em>†</td>
<td>269–300</td>
<td>14–19</td>
<td>Pointed, subterminal (dorsal) oral opening</td>
<td>Gradually tapered to the extremity</td>
<td>Deep dorsal incisure and shallower ventral incisure</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><em>Oslerus rostratus</em>‡</td>
<td>335–412</td>
<td>18–20</td>
<td>Oral opening central to the head and surrounded by a cuticular ring with dorsal and ventral prominences</td>
<td>Deep incisure in the ventral side with a cuticular spine#</td>
<td>–</td>
<td>–</td>
<td>5,63</td>
</tr>
<tr>
<td><strong>Eggs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Capillaria aerophila</em></td>
<td>60–65</td>
<td>25–40</td>
<td>–</td>
<td>–</td>
<td>Asymmetrical</td>
<td>Striated outer shell with a network of anastomosing ridges and bridges</td>
<td>65</td>
</tr>
<tr>
<td><em>Trichuris campanula</em>§</td>
<td>63–85</td>
<td>34–39</td>
<td>–</td>
<td>–</td>
<td>Symmetrical</td>
<td>–</td>
<td>4</td>
</tr>
<tr>
<td><em>Trichuris serrata</em>§</td>
<td>54</td>
<td>40</td>
<td>–</td>
<td>–</td>
<td>Symmetrical</td>
<td>–</td>
<td>4</td>
</tr>
<tr>
<td><em>Aonchotheca putorii</em>¶</td>
<td>57–66</td>
<td>21–28</td>
<td>–</td>
<td>–</td>
<td>Thickened ridges</td>
<td>Rough surface</td>
<td>4</td>
</tr>
<tr>
<td><em>Pearsonema feliscati</em>¶</td>
<td>51–65</td>
<td>24–32</td>
<td>–</td>
<td>–</td>
<td>Asymmetrical</td>
<td>Pitted surface with bleb-like striations</td>
<td>4</td>
</tr>
<tr>
<td><em>Capillaria hepatica</em>¶</td>
<td>51–68</td>
<td>30–35</td>
<td>–</td>
<td>–</td>
<td>Asymmetrical</td>
<td>Highly striated shell</td>
<td>4</td>
</tr>
</tbody>
</table>

*A minimum length of ~300 µm has been reported in cases confirmed by histological64 and genetic characterisation22
†To date, recorded in only two domestic cats, in Malawi66 and in Sicily23
‡To date, described in domestic cats in limited areas: Sri Lanka, Majorca, Hawaii,67–69 Sicily,70 Sardinia71 and northern Spain63
§To date, recorded extremely rarely in certain regions;4 taxonomical identity has been questioned4
¶Parasite with a non-respiratory localisation
∞Larvae found in bronchi or trachea measured 300–320 µm in length;6 growth during larval passage in faeces has been hypothesised as a cause of the size variation5,72
#Slight individual variation in shape of the caudal end has been reported6
New diagnostic methods
Innovative assays have been validated for the genetic identification of *A. abstrusus*, *T. brevior* and *C. aerophila* in different biological samples. A duplex PCR based on markers within the ribosomal (rDNA) internal transcribed spacer 2 region (ITS2) was developed to discriminate between faecal L1s of *A. abstrusus* and *T. brevior* in a single cat with a mixed infection.73 The two metastrongyloids may also be identified by species-specific nested PCRs based on differential markers within the ITS2 region; high sensitivity and specificity was verified on large subsets of samples.26,27 Very recently, a triplex assay has been validated for the simultaneous discrimination of *A. abstrusus*, *T. brevior* and *Angiostrongylus chabaudi*;74 the last is a very rare cardiopulmonary nematode of wild felids that has been recorded in a mixed infection with lungworms in a domestic cat.75

Recently developed molecular assays have proved powerful for the diagnosis of feline aelurostrongylosis and troglodylostylosis, overcoming the constraints of classical methods.

All of these recently developed molecular assays have proved powerful for the diagnosis of feline aelurostrongylosis and troglodylostylosis, overcoming the constraints of classical diagnosis. The PCR assay specific for *A. abstrusus* was validated on a panel of faecal (ie, faces, flotation supernatant, Baermann sediment) and pharyngeal swab samples from infected cats. It showed a specificity of 100% and a sensitivity of ~97%, and was able to reveal infected cats.

### Treatment

**A. abstrusus**

Treatment of *A. abstrusus* infection with off-label parasiticides has been described in research papers and textbooks. For example, the use of ivermectin for treating aelurostrongylosis is reported in single animals and limited case series, but this macrotricide has inconsistent activity.16,48,77-79 Two doses are described for off-label ivermectin,16 but care is required in kittens.80 Two doses of off-label abamectin, 300 µg/kg subcutaneously (SC), 2 weeks apart, have also been used for treating *A. abstrusus*.79

Several studies have evaluated the efficacy and safety of feline parasiticides against *A. abstrusus*. An oral paste containing 18.75% fenbendazole (Panacur; MSD Animal Health) is licensed in some countries (eg, UK) for the treatment of *A. abstrusus* at a dosage of 50 mg/kg PO for 3 consecutive days, and this treatment regimen has an efficacy of 99.29%.81,82 Two spot-on parasiticides, one containing imidacloprid 10% and moxidectin 1% (Advocate; Bayer Animal Health), and the other containing emodepside 2.1% and praziquantel 8.6% (Profender; Bayer Animal Health), were compared with the formulation containing oral fenbendazole in treating feline aelurostrongylosis.83,84 The emodepside 2.1%/praziquantel 8.6% spot-on and the fenbendazole paste showed similar therapeutic performances (99.38% vs 99.29%), while the imidacloprid 10%/moxidectin 1% spot-on was 100% effective in stopping larval shedding and in curing clinical signs.81,82 This formulation (Advocate; Bayer Animal Health) is licensed in some markets (eg, Australia) for the treatment of cat aelurostrongylosis. Additionally, the adulticidal efficacy of emodepside has been demonstrated in two randomised, placebo-controlled experimental trials to be up to 99.2%. These studies showed that two spot-on administrations of emodepside 2 weeks apart are safe and efficacious against cat aelurostrongylosis.83

Another macrocyclic lactone, selamectin (Stronghold; Zoetis), used topically at 18 mg/kg, reduced clinical signs after a single spot-on administration, while a second dose after 1 month ensured improvement in respiratory function and radiographic bronchial lesions.84 Selamectin at a topical dose of 6 mg/kg was effective in eliminating larvae from the faeces of a cat after 30 days;85 the same drug was effective in producing a clinical recovery and stopping larval shedding in 9/10 cats infected with *A. abstrusus*.86 Milbemycin oxime 4 mg/kg (plus praziquantel 10 mg/kg) (Milbemax; Novartis Animal Health) PO at 2 week intervals was also effective in stopping L1 elimination and resulted in resolution of clinical signs over a period of 6 weeks in a cat with clinical aelurostrongylosis.86

A novel topical formulation containing fipronil 8.3% w/v, (S)-methoprene 10% w/v, eprinomectin 0.4% w/v and praziquantel 8.3% w/v (Broadline; Merial) was evaluated for efficacy against larval and adult *A. abstrusus* in experimentally infected cats.87 This formulation is licensed in some countries for the treatment of *A. abstrusus*. Using treatment time points based on the life cycle of *A. abstrusus* in the cat (ie, from inoculated L3s to adult stages), the study demonstrated that eprinomectin has high efficacy against all *A. abstrusus* stages; for example, 99.6% efficacy against adult stages in the feline definitive host.88 In cats naturally infected with *A. abstrusus*, this formulation showed 99.6% efficacy based on larval counts.89

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that were copromicroscopically negative. The assays have proved successful and presence of PCR inhibitors in faecal samples, the laboriousness of DNA extraction from faeces, parasite prepatent and migration periods, of adequate faecal collection in the field, long longevity and practicality (avoiding the difficulties of molecular diagnosis of swab is the most suitable sample for the occurrence of A abstrusus and T brevior in cat populations and the efficacy of parasiticides in clinical settings. A similar diagnostic assay specific for a

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**T brevior**

Information on control options for troglostrongylosis in domestic cats is incomplete. The administration of imidacloprid 10%/moxidectin 1% (Advocate) in a cat appeared unsuccessful, but this may have been due to the severe clinical signs and extensive lung lesions already present at the point of referral. A kitten infected with T brevior returned negative scores upon both copromicroscopic and biomolecular examinations for 3 months after a single administration of Advocate and showed a corresponding improvement in severe cardiopulmonary signs. A single administration of milbemycin oxime 2 mg/kg (Milbemax) was efficacious in stopping larval shedding in one cat with a subclinical mixed infection of A abstrusus and T brevior, but the same drug was effective only against A abstrusus in another cat from the same litter, which died due to infection with T brevior despite the treatment. The topical formulation containing emodepside 2.1%/praziquantel 8.6% (Profender) recently showed promise in the treatment of two kittens with mixed lungworm infections (T brevior and either A abstrusus or C aerophila). Respiratory signs resolved after one or two administrations of the spot-on solution, and larval (T brevior and A abstrusus) and egg (C aerophila) shedding was also eliminated 2–4 weeks after treatment. The spot-on containing eprinomectin (Broadline) proved 100% efficacious in stopping larval shedding in a few cats with natural T brevior infection. It recently showed 100% efficacy against developing larvae and adults of T brevior under experimental conditions.

**C aerophila**

Available data on the treatment of C aerophila infection in cats include reports on the efficacy of repeated administrations of a variety of dosages of injectable or oral levamisole and off-label abamectin. Importantly, the spot-on formulation containing moxidectin 1% (Advocate), which was efficacious against uroleurostrongylosis, demonstrated ~99.8% efficacy in stopping egg shedding and eliminating clinical signs in cats with lung capillariosis. The safety and efficacy of the topical combination containing eprinomectin (Broadline) was evaluated against helminths, including Capillaria species, in domestic cats. An efficacy of 99.6% in reducing counts of Capillaria eggs was reported after treatment. Although no morphological identification of the eggs was performed, it was assumed that the vast majority were C aerophila. A very recent study has demonstrated that a single treatment with Broadline in naturally infected cats is able to reduce the C aerophila parasite burden and to lower or eliminate faecal egg shedding.

Any respiratory sign in an at-risk cat (eg, free-roaming or kitten) should ring an alarm bell for clinicians working in lungworm-endemic areas or with travelling pets.
**Current and future priorities**

Lungworms are gaining more attention in veterinary medicine. More frequent identification of feline lungworm disease could be due to increased prevalence of infections, expanding geographic range, increased awareness, or a combination of these factors. However, it is likely that in certain areas (eg, Europe) lungworms will be increasingly recognised as having a clinical role in respiratory disease of cats.

**Practitioner vigilance**

From a practical perspective, lungworms infecting cats can be problematic to identify and diagnose, even in the presence of clinical signs. Indeed, any respiratory sign in an at-risk cat (eg, free-roaming animals, kittens) should always ring an alarm bell for clinicians working in endemic areas or with travelling pets. Any suspected case should undergo appropriate diagnostic work-up and, especially in endemic areas, even apparently healthy cats should be screened regularly for lungworms. A routine check for metastrongyloid infection is of importance also for any cat in an endemic region that requires general anaesthesia, given the potential fatal risks associated with lungworm infections.

Practitioners should be highly conscious of the importance of lungworms, especially *A. abstrusus*, and must be vigilant for these infections, both in cats living in endemic areas and cats living in territories considered free of infection. These nematodes may be easily introduced into free regions, and thus they should not be overlooked in the presence of compatible clinical signs or ruled out in apparently healthy cats. Veterinarians should start routinely applying the Baermann migration technique (currently infrequently utilised in practice) and perform a careful appraisal of trichurid eggs in cat faeces.

**Veterinarians should start routinely applying the Baermann migration technique and perform a careful appraisal of trichurid eggs in cat faeces.**

**Current armoury**

The above advice assumes particular importance in the light of the fact that, in most cases, lungworm treatment protocols are straightforward and effective, especially against *A. abstrusus* and *C. aerophila*. To summarise the treatment data discussed on pages 14 and 15:

- Spot-on moxidectin/imidacloprid was effective in stopping larval and egg shedding, respectively, by *A. abstrusus* and *C. aerophila*, and in curing clinical signs in naturally infected cats.
- Spot-on emodepside, selamectin and eprinomectin similarly showed high efficacy in the treatment of aelurostrongylosis in natural and/or experimental conditions.
- Clinical reports in single animals have documented promising activity of moxidectin and emodepside in curing *T. brevior* infection.
- Spot-on eprinomectin proved to be efficacious in stopping larval shedding in cats with natural *T. brevior* infection, as well as against both developing larvae and adults of *T. brevior* under experimental conditions.
- Faecal egg shedding of *C. aerophila* can be reduced or eliminated following a single treatment with eprinomectin. Also, cats treated with eprinomectin harboured significantly fewer *C. aerophila* lungworms compared with untreated cats.
- Oral milbemycin oxime has been effective in treating single cases of *A. abstrusus* or *T. brevior* infection.
- Topical emodepside was effective in treating a case of lung capillariosis, suggesting that a formal evaluation of this formulation for treating *C. aerophila* is worthwhile.

Further field studies involving larger numbers of cases are necessary to evaluate the efficacy of milbemycin oxime against *A. abstrusus*, *T. brevior* and *C. aerophila*; of selamectin against *T. brevior* and *C. aerophila*; and of moxidectin and emodepside against *T. brevior*. Such studies should take into account the observation that anthelmintic efficacy in treating *T. brevior* seems greatly dependent on the age of the cat, parasite burden, timing and number of administrations, presence and severity of lung damage, and/or host immunity.

**New avenues for control**

The potential efficacy of parasiticides in the prevention of metastrongyloid infections opens new avenues for the control of cat lungworms. As a key example, spot-on moxidectin has proved effective in preventing (and treating) infection caused by the closely related parasite *A. vasorum*. It has also been shown that dogs in areas endemic for *A. vasorum* treated every 3 months with milbemycin oxime are half as likely to be infected as those that are not treated, and that monthly treatments with this molecule have the potential to prevent the establishment of *A. vasorum* in dogs. Given that these anthelmintics and others (eg, emodepside, selamectin) have shown efficacy in treating lungworms, further studies are warranted to investigate this management option. However, identifying a risk season for seasonal chemoprevention of lungworms is difficult. Recommendations for chemoprevention would have to consider each local...
epidemiological situation and take into account the fact that paratenic hosts of *A. abstrusus* and *T. brevior* may be present throughout the year.

The activity of eprinomectin in the chemoprevention of aelurostrongylosis when administered against prepatent developmental stages in experimental conditions is truly promising from a clinical perspective. Administration of this parasiticide is able to limit the progressive pulmonary changes usually occurring during the course of infection. Field studies are, however, required to support this efficacy, and to evaluate the activity of other anthelmintics in the prevention of cat lungworm infections.

Moxidectin needs to be considered for its important pharmacokinetic properties. This drug remains at detectable levels for weeks after treatment, and it has been demonstrated that consistent administrations of topical spot-on formulations containing moxidectin induce elevated and sustained steady-state plasma concentrations. Thus, repeated administration of moxidectin has the potential to protect animals prospectively against parasites. For instance, the steady-state in cats is reached after three to five treatments, and this protected against infection by hookworms and *Dirofilaria immitis*. Studies evaluating the efficacy of moxidectin steady-state in protecting from subsequent infection by lungworms would be very interesting in terms of offering further approaches in the management of these infections.

‘Novel’ lungworms

From an epidemiological perspective, if the current trends in the apparent expansion of feline lungworms continue, we will face an increasing number of clinical cases in a variety of geographic areas. Additionally, other little-known lungworms could gain more importance. For instance, the metastrongyloid *Troglostrongylus subcrenatus* has so far only been recorded in two cats, one in Malawi, the other in Sicily. *Oslerus rostratus* has previously only been described in cats in limited areas including Sri Lanka, Majorca and Hawaii; however, more recently, there have been reports in two single cats from Sicily and Sardinia. Further diagnostic and clinical problems will arise if more cats infected by these two lungworms are identified in wider geographic regions, because their L1s are similar to those of other metastrongylids and there are no known therapeutic options. This is especially relevant given that these ‘novel’ lungworms may be described in mixed infections, making a definitive diagnosis at the species level truly complicated.

**Summary**

Continuous awareness of lungworms affecting cats is crucial to further elucidate their geographic distribution and document possible expansion, to refine diagnostic techniques and to improve the current methods available for treatment and prevention of respiratory parasitoses.

**Acknowledgements**

The authors thank all of the following friends and colleagues for their valuable participation in studies on feline respiratory nematodes: Fabrizia Veronesi, Andrea Boari, Antonio Frangipane di Regalbono, Anastasia Diakou, Paolo Emidio Crisi, Emanuela Di Giulio, Silvana Meloni, Raffaella Iorio, Barbara Paolotti, Roberto Bartolini, Giulia Morganti and Giuseppe Castagna. The authors are grateful to Matilde Vicovaro for the drawings in Figures 1 and 2.

**Funding**

The authors received no financial support for the research, authorship and/or publication of this article.
**Conflict of interest**

ADC holds a post-doc fellowship on parasites other than feline lungworms and she has participated in the present review in the framework of her freedom of scientific research.

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