Updates on emerging and evolving gastrointestinal parasites in dogs and cats

Gastrointestinal parasites are a common veterinary concern and pet owner conversation. Globally, parasite ranges and abundances are evolving, and various clinical management challenges in dogs and cats have emerged. Some of these are novel, such as hookworm multi-drug resistance, and others have been veterinary challenges for years, like *Giardia*'s zoonotic potential. For these examples and others, there has been increased awareness of the need for appropriate veterinary anthelmintic use and stewardship. This review provides an update on selected gastrointestinal parasites of One Health importance, highlights gastrointestinal parasite global management and prevention recommendations, and summarises recent research, along with potential risks associated with pet importation and travel. Suggestions on freely available online resources to assist with practical veterinary clinical management (screening, diagnosis, treatment, prevention) and pet owner communication, along with addressing One Health and antiparasitic stewardship concerns, are provided from a global perspective, for example The European Scientific Counsel for Companion Animal Parasites. Clinical cases are drawn from molecular diagnostic faecal surveillance of dogs and cats during 2022 and 2023, and include the following gastrointestinal parasites with zoonotic potential: hookworms (*Ancylostoma caninum*), tapeworms (*Echinococcus multilocularis*), roundworms (*Baylisascaris procyonis*) and *Giardia*.

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Parasites have long been a part of day-to-day routine veterinary care worldwide. As new veterinary management challenges have emerged in north America, such as hookworm multi-anthelmintic drug resistance, there have been other recently described changes in parasite frequencies, distributions and emergence (locally, regionally and worldwide). Detection of gastrointestinal parasite resistance and potential zoonotic concerns through recently introduced (and readily available in north America for screening and diagnosis) faecal testing methods (for example, molecular diagnostics), have highlighted the need for anthelmintic stewardship and communication of human health risk worldwide. Further, global veterinary guidelines for gastrointestinal parasite management, alongside recognition of the infectious disease impacts of pet importation and travel, have raised awareness of the clinical implications of canine parasites (current, emerging and evolving), One Health and subsequent need for veterinary attention to gastrointestinal parasite management and pet-owner communication. Clinical examples of gastrointestinal parasites of One Health importance will be used to spotlight these concerns and raise awareness of resources for veterinary management, the latter of which include guidelines from the European Scientific Counsel Companion Animal Parasites, the Companion Animal Parasite Council, the Canadian Parasitology Expert Panel and the Tropical Council for Companion Animal Parasites.

Echinococcus multilocularis tapeworms in British Columbia, Canada

This case concerns a young female entire Border Collie who initially presented for reduced appetite and weight loss, and shortly thereafter developed bloody diarrhoea. Clinical history revealed that she was not currently on endoparasite prevention, lived on a sheep farm and was intermittently fed a raw meat-based diet, including the occasional sheep carcass. Physical examination was

reported as a thin dog, with no other significant clinical findings aside from diarrhoea. The veterinarian treated her with metronidazole and milbemycin oxime/praziquantel and submitted a faecal sample as part of an infectious disease work-up. The dog improved rapidly (within 48 hours) and a faecal quantitative polymerase chain reaction test detected *Echinococcus multilocularis* (*Figure 1*). This polymerase chain reaction panel test detects 20 common gastrointestinal parasites, along with markers for hookworm benzimidazole treatment resistance and *Giardia* assemblages with zoonotic potential.

E. multilocularis is a tapeworm of emerging concern in parts of Europe and north America (Canadian Parasitology Expert Panel, 2019; Companion Animal Parasite Council, 2023; European Scientific Counsel Companion Animal Parasites, 2023). In their respective regions, foxes, raccoon dogs, wolves, domestic dogs and other wild canids can serve as definitive hosts and are a significant reservoir for infection, with adult parasite development in their intestine occurring after consuming the parasite (metacestode) in the liver of a rodent (the intermediate host). The life cycle continues with tapeworm eggs shed through faeces into the environment. Eggs are immediately infective, and dogs may become infected through ingestion (eggs in food, water, the environment) or auto-infection (Davidson et al, 2013; Canadian Parasitology Expert Panel, 2019; Evason et al 2023a; Companion Animal Parasite Council, 2023; European Scientific Counsel Companion Animal Parasites, 2023). However, dogs may also be an aberrant (dead-end) intermediate host and develop alveolar echinococcosis, which can be fatal in both dogs and humans (Davidson et al, 2013; Canadian Parasitology Expert Panel, 2019; Companion Animal Parasite Council, 2023; European Scientific Counsel Companion Animal Parasites, 2023; Evason et al, 2023a; Fisher et al, 2023).

Diagnosis of (and differentiation from *Taenia* spp.) intestinal *E. multilocularis* in dogs through faecal surveillance may alert to human exposure risk (Evason et al, 2023a; Leutenegger et al, 2023).

In this case, treatment and ongoing prevention is achieved through limiting access to raw meat (offal) and wild rodent consumption, and for dogs at high risk (for example, those that live in endemic region or are imported from one) appropriate anthelmintic use with praziquantel or a praziquantel containing product (Canadian Parasitology Expert Panel, 2019; Companion Animal Parasite Council, 2023; European Scientific Counsel Companion Animal Parasites, 2023).

The dog's veterinarian worked with infectious disease specialists to ensure she was treated and followed up appropriately. The dog's owners were advised to connect with their human health care provider and public health was notified, despite *Echinococcus* not being reportable in British Columbia, Canada (Evason et al, 2023a). In the UK, compulsory tapeworm treatment of dogs will hopefully continue to ensure that the region remains free of this parasite, and a recent study testing dogs only found one dog (which had been illegally imported) infected with tapeworm, which was molecularly identified as *Taenia serialis* (European Scientific Counsel Companion Animal Parasites, 2023; Fisher et al, 2023).

Figure 1. Adult Echinococcus multilocularis superimposed on a Canadian dime.

Hookworm (*Ancylostoma caninum*) treatment resistance in Toronto, Canada

This case was an approximately 8 week old puppy presenting with his owner for his very first veterinary visit. The puppy was considered healthy and age appropriate in development, on clinical history and physical exam. Among the variety of pet-owner 'puppy' topics (such as vaccination, behaviour and nutrition) communicated during his visit, his veterinarian also discussed endoparasite prevention. After this conversation with the owner, and communication of regional parasite guidelines (Canadian Parasitology Expert Panel, 2019; Companion Animal Parasitology Council, 2023), a faecal test was submitted. Unsurprisingly, in a puppy of this age and history, the result indicated infection with canine hookworm.

The hookworms, *Ancylostoma* and *Uncinaria* spp. are some of the most encountered gastrointestinal parasites in dogs worldwide. At this time, *A. caninum* is considered uncommon in the UK, and little is known regarding potential resistance emergence. Clinical disease can be severe in young puppies with heavy hookworm burdens, due to aggressive worm feeding (causing anaemia). Typically, adult dogs have subclinical disease or less severe clinical signs (Weese and Evason, 2019). Hookworms, specifically the L3 larvae, can infect dogs through multiple means (*Figure 2*; Evason et al, 2023b), and in the present case, were most likely transferred from his mother while nursing (Canadian Parasitology Expert Panel, 2019; Companion Animal Parasite Council, 2023; European Scientific Counsel Companion Animal Parasites, 2023; Evason et al, 2023b). Additionally, hookworm larvae can be present in an arrested development phase within the dog's tissues (*Figure 3;* Evason et al, 2023b), and then become re-activated after anthelmintic therapy, a phenomenon referred to as 'larval leak'. Global parasite guidelines (Canadian Parasitology Expert Panel, 2019; Companion Animal Parasite Council, 2023; European Scientific Counsel Companion Animal Parasites, 2023; Tropical Council for Companion Animal Parasites, 2023) pro-

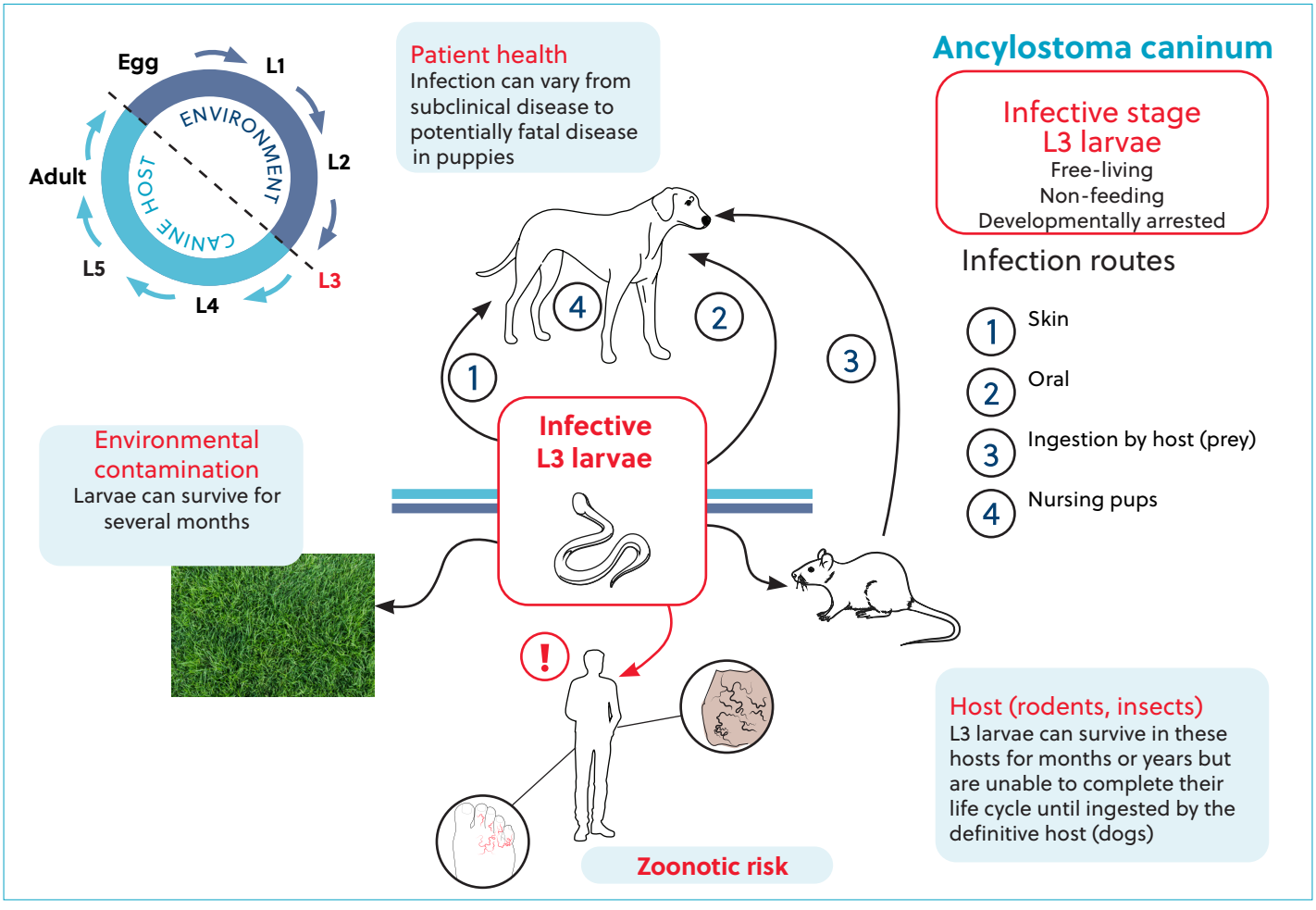

Figure 2. Life cycle of canine hookworm, Ancylostoma caninum (image reproduced with permission of MARS Pet Care/Antech Diagnostics, Education).

vide resources for bitch, puppy and adult dog management (for example, deworming and testing) of hookworms, along with overall parasite preventive care.

In the USA, hookworm drug (anthelmintic) resistance has evolved into an increasingly common veterinary challenge (Jiminez Castro et al, 2019; Marsh and Lakritz, 2023; Leutenegger, 2023b; Leutenegger et al, 2023). At present, multi-anthelmintic drug resistance exists for the following commonly used veterinary medications (Jiminez Castro et al, 2019; Jiminez Castro et al 2021; Jiminez Castro et al, 2022; Venkatesan et al, 2023):

- Benzimidazoles (such as fenbendazole and febantel)
- Macrocyclic lactones (such as avermectin and milbemycin)
- Tetrahydropyrimidine (such as pyrantel).

Unfortunately, hookworm resistance has rapidly spread across the USA, and is no longer confined to the southern states like Florida (Leutenegger, 2023a; 2023b; Leutenegger et al, 2023; Venkatesan et al, 2023). Resistance is not isolated to the Greyhound breed, from which it is theorised to have emerged, as a result of anthelmintic selection pressure in Florida racing Greyhound kennels (Jiminez Castro et al, 2019; Jiminez Castro et al, 2021; Jiminez Castro et al, 2022). Recent research has described detection of benzimidazole (such as fenbendazole and febantel) hookworm treatment resistance as widespread across north America, and within more than 70 dog breeds (Leutenegger, 2023a; 2023b; Leutenegger et al, 2023).

Recently, a case series of dogs with hookworm treatment resistance was reported in Canada, with some of these dogs having a history of importation (from the USA) and some of the dogs lacking a USA travel history (Evason et al, 2023b). This study indicates that drug resistance is now endemic to some degree in Canada and raises speculation of multi-anthelmintic drug resistance emergence in other countries beyond those previously described, such as Nigeria (Idika et al, 2016; Evason et al, 2023b; Nezami et al, 2023). As hookworms are zoonotic, and some of the above anthelmintics are used for human treatment, multi-anthelmintic drug resistance has implications for human health. Veterinary efforts to identify hookworm infections (and any resistance) through routine faecal screening and attention to dogs with persistent hookworm infections to detect suspect resistance, and consider additional testing (such as serial faecal egg count reduction testing, quantitative polymerase chain reaction panels with resistance markers) allows for targeted treatment and practical antiparasitic stewardship.

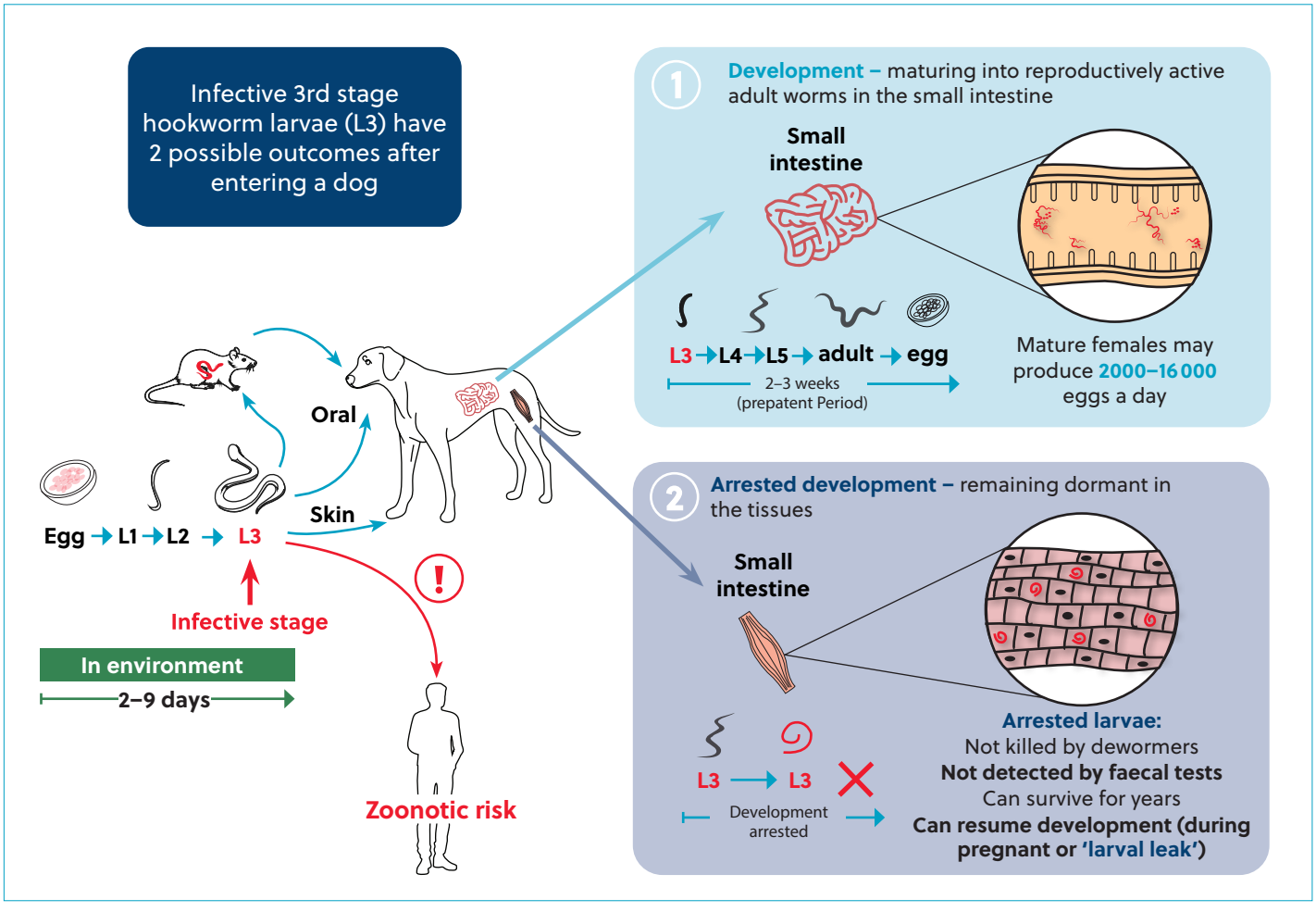

Figure 3. Overview of hookworm 'larval leak' (image reproduced with permission of MARS Pet Care/Antech Diagnostics, Education).

Fortunately, the diagnosed hookworm infection in this case did not concurrently detect the benzimidazole treatment resistant marker on the dog's quantitative polymerase chain reaction panel result. The dog's veterinarian and owner followed guidelines for appropriate treatment and hookworm re-assessment testing (Canadian Parasitology Expert Panel, 2019; Companion Animal Parasite Council, 2023) and he went on to develop normally. The dog's veterinarian was informed of the change in local (Canada) anthelmintic resistance patterns for hookworm and was mindful of this emerging risk. In Canada, hookworm treatment resistance may have begun with imported dogs from the USA, but this type of resistance is now endemic within the country and has clinical implications for available veterinary drug use, as once resistance has developed to one drug its utility is limited (Evason et al, 2023b). Globally, due to dog importation and travel, there could be the possibility of multi-anthelmintic drug resistance emerging in other regions (Evason et al, 2023b).

Baylisascaris procyonis, Raccoon roundworms in California, USA

This case concerns an adult male neutered hound whose veterinarian performed routine faecal testing as part of his annual wellness and health check (Companion Animal Parasite Council, 2023). The test later detected *Baylisascaris procyonis*. No one at the clinic felt comfortable with their communication of the specific (and potentially severe) zoonotic aspects of *Baylisascaris procyonis*, as compared to their routine conversations around *T. canis* and zoonotic parasites in general. No one at the clinic had realised that *B. procyonis* was zoonotic, and staff were understandably concerned about communication with the pet-owner. Hospital staff reached out to infectious disease specialists and parasitologists for assistance with management and One Health communication.

The roundworm, *Baylisascaris procyonis*, is highly prevalent in raccoons, and can be found in north American dogs as an incidental finding, occurring in faeces due to either transient egg shedding or true enteric infection (Canadian Parasitology Expert Panel, 2019; French et al, 2019; Companion Animal Parasite Council, 2023). Typically, infection with *B. procyonis*, does not cause clinical disease in dogs (or in humans); however, neural migrans has been described in infected dogs (Gavin et al, 2005). Similarly, this parasite rarely causes disease in humans, but can cause neurological symptoms when it does occur (Gavin et al, 2005). The parasite is often misidentified as *T. canis*; however, the two roundworms can be differentiated through faecal quantitative polymerase chain reaction or close microscopic exam, (differences include the pitted outer shell of *T. canis* and a slight size difference in eggs).

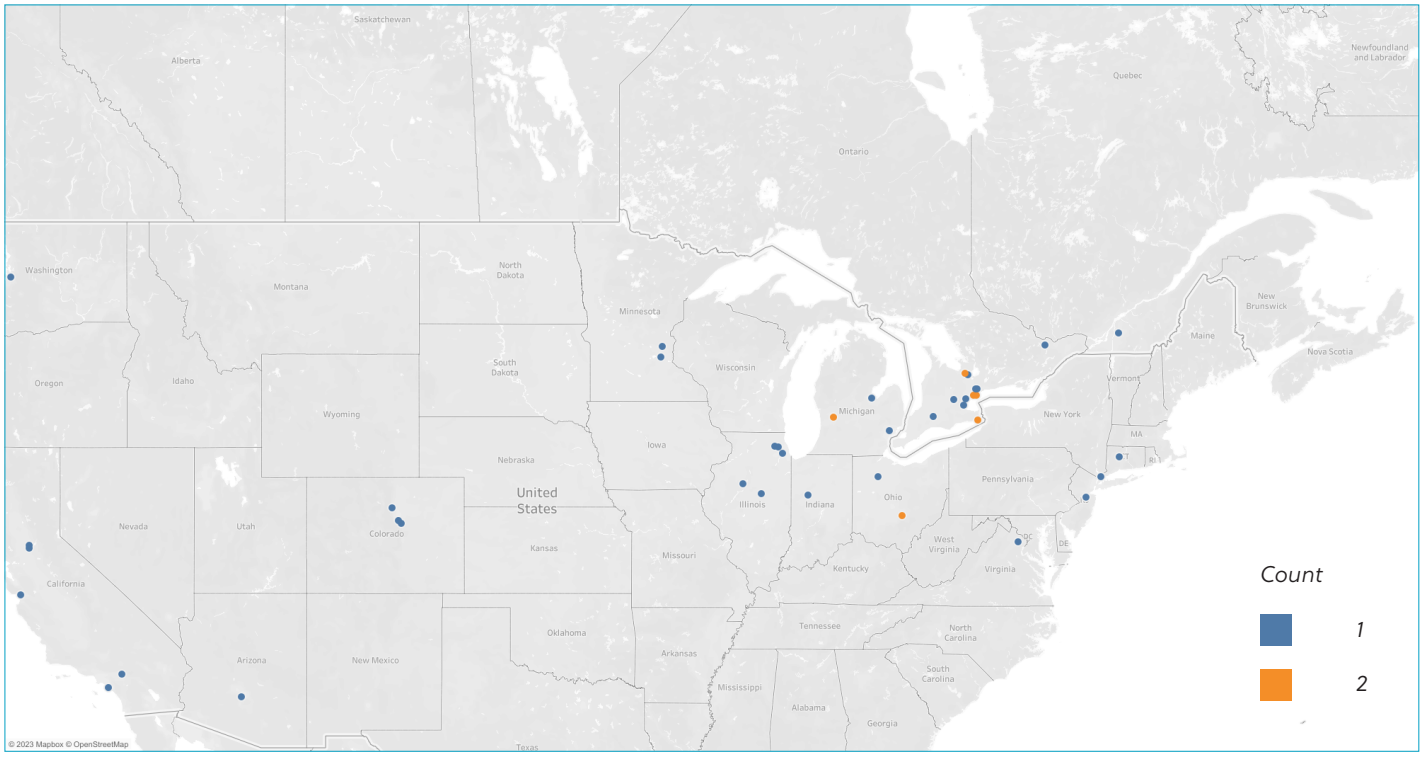

Figure 4. North American location of dogs with detected Baylisascaris procyonis, n=47 (45 dogs, 1 cat and 1 skunk). Map courtesy of JS Weese, used with permission.

Recent canine faecal surveillance research has detected widespread *B. procyonis* in multiple regions of the USA and Canada (*Figure 4*; Leutenegger, 2023b). In Europe, a study in Norway described infection with this parasite in racoons and raccoon dogs that were illegally imported (Davidson et al, 2013). Detection of roundworm eggs in at risk dogs, or in endemic regions, should prompt parasite differentiation (from *T. canis*) and immediate treatment with routine dewormers (Canadian Parasitology Expert Panel, 2019; Companion Animal Parasite Council, 2023). In cases of raccoon roundworm, effective treatment of the dog and immediate communication of the diagnosis with the owner to raise awareness around reduction of exposure to raccoons and their zoonotic infectious disease risk should occur (Canadian Parasitology Expert Panel, 2019; French et al, 2019; Companion Animal Parasite Council, 2023).

Giardia duodenalis

This case concerns a middle-aged dog who presented with his owner for a 3–4 week history of diarrhoea (intermittent initially, and now several times daily). As part of an infectious disease work-up, the veterinarian performed a faecal assessment (via quantitative polymerase chain reaction) which detected *Giardia duodenalis* and the marker for *G. duodenalis* assemblages of zoonotic potential (assemblages A/B).

Dogs infected with *Giardia duodenalis* can be very challenging for veterinarians. This protozoal parasite can result in clinical disease (typically acute or chronic diarrhoea), or dogs can test positive and not have any clinical signs (Companion Animal Parasite Council, 2023; European Scientific Counsel Companion Animal Parasites, 2023). In dogs with clinical signs consistent with infection (like diarrhoea) that test positive, treatment is currently advised (Companion Animal Parasite Council, 2023; European Scientific Counsel Companion Animal Parasites, 2023). However, dogs lacking clinical signs that test positive frequently raise questions from pet owners (and veterinary teams) regarding whether treatment should be initiated or not. At present, most parasitologists, infectious disease specialists, the Companion Animal Parasite Council (2023) and the European Scientific Counsel Companion Animal Parasites (2023) do not advise treating dogs lacking clinical signs, as part of appropriate antiparasitic use and stewardship.

Challenges arise when dogs lacking clinical signs that test positive are refused entry at their daycare, dog park or other dog group setting, or concerns regarding environmental shedding (for example by shelters, kennels or dog parks) are raised. More questions around treatment (and antiparasitic use) can occur when the concern regarding *Giardia*'s zoonotic potential arise, as without confirmatory testing for zoonotic potential veterinarians should probably assume human risk is present (Marsh and Babcock, 2015; Companion Animal Parasite Council, 2023). More questions can occur when these pet owners are considered high-risk for zoonotic infection – for example the young, elderly and immunocompromised.

There are other clinical questions associated with *Giardia*, along with those currently swirling in the infectious disease world as to whether this parasite should now be considered 'background noise' due to its prevalence globally. Examples of *Giardia* prevalence include one recent study (Leutenegger, 2023b) of over 300 000 faecal samples from pets in north America, which described detection in dogs ranging from 14–17%, with just under

4% of those detecting with the marker for *Giardia* with zoonotic potential. In this same study, *Giardia* detection in cats ranged from 6.3–7.5%, and of those, 11.8–19.1% were *Giardia* with zoonotic potential from Canada and the USA, respectively (Leutenegger, 2023b). In Western Europe, a recent study of local canine sites (Drake et al, 2022) reported that of the 22.8% of dogs who were positive for a gastrointestinal parasite, *Giardia* was the most common (17.3%).

In the present case, treatment with fenbendazole (a 3-day course at 50 mg/kg orally once daily), together with bathing to remove cysts and concurrent removal of faeces from the dog's yard, led to a rapid improvement of his clinical signs (Companion Animal Parasite Council, European Scientific Counsel Companion Animal Parasites). Careful questioning of the owner did not reveal high-risk humans and proper hand hygiene and communication of risk was completed by his veterinarian.

Conclusions

Ongoing pet (and human) risk assessment and gastrointestinal parasite preventive care, combined with attention to anthelmintic stewardship, will likely be needed as more research emerges globally on endoparasite frequency and distribution. Following global guidelines for parasite testing and veterinary faecal surveillance, should help shed light on where these parasites are emerging, how widespread this distribution may be, identify how they are evolving (for example, any emerging drug resistance) and ensure appropriate antiparasitic use, while alerting to One Health concerns. CA

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Conflict of interest:

The author is an employee of Antech Diagnostics, MARS Petcare Science & Diagnostics. The real-time qPCR test was KeyScreen® GI Parasite PCR, an Antech product.

KEY POINTS

- Gastrointestinal parasites are a common part of day-to-day veterinary practice.
- Gastrointestinal parasite ranges and abundances are evolving.
- Canine gastrointestinal parasites may have One Health importance, such as hookworms, tapeworms, roundworms and *giardia*.
- Global gastrointestinal parasite resources can help with veterinary management and pet owner counselling.
- Appropriate veterinary anthelmintic use is needed.

References

Canadian Parasitology Expert Panel. Guidelines for the Management of Parasites in dogs and cats. 2019. https://research-groups.usask.ca/cpep/index.php#Protocol (last accessed 2 October 2023)

Companion Animal Parasite Council. Intestinal Parasite Guidelines. 2023. https://capcvet.org/guidelines/ (last accessed 2 October 2023)

Davidson RK, Øines Ø, Hamnes IS, Schulze JE. Illegal wildlife imports more than just animals – Baylisascaris procyonis in raccoons (Procyon lotor) in Norway. J Wildl Dis. 2013;49(4):986–990. https://doi.org/10.7589/2012-06-154

Drake J, Sweet S, Baxendale K et al. Detection of Giardia and helminths in Western Europe at local K9 (canine) sites (DOGWALKS Study). Parasit Vectors. 2022;15(1):311. https://doi.org/10.1186/s13071-022-05440-2

European Scientific Counsel Companion Animal Parasites (ESCCAP). Worm Control in Dogs and Cats. 2023. https://www.esccap.org (last accessed 2 October 2023

Evason MD, Jenkins EJ, Kolapo TU, Mitchell KD, Leutenegger CM, Peregrine AS. Novel molecular diagnostic (PCR) diagnosis and outcome of intestinal Echinococcus multilocularis in a dog from western Canada. J Am Vet Med Assoc. 2023a;261(9):1–3. https://doi.org/10.2460/javma.23.03.0179

Evason MD, Weese JS, Polansky B, Leutenegger CM. Emergence of canine hookworm treatment resistance: Novel detection of Ancylostoma caninum anthelmintic resistance markers by fecal PCR in 11 dogs from Canada. Am J Vet Res. 2023b;84(9):ajvr.23.05.0116. https://doi.org/10.2460/ajvr.23.05.0116

Fisher MA, Rees B, Capner C, Pritchard S, Holdsworth PA, Fitzgerald RA. A survey of gastrointestinal parasites in dogs illegally entering the UK (2015–2017). Vet Rec Open. 2023;10(1):e54. https://doi.org/10.1002/vro2.54

French SK, Pearl DL, Peregrine AS, Jardine CM. Baylisascaris procyonis infection in raccoons: a review of demographic and environmental factors influencing parasite carriage. Vet Parasitol Reg Stud Reports. 2019;16:100275. https://doi.org/10.1016/j.vprsr.2019.100275

Gavin PJ, Kazacos KR, Shulman ST. Baylisascariasis. Clin Microbiol Rev. 2005;18(4):703–718. https://doi.org/10.1128/CMR.18.4.703-718.2005

Idika IK, Ezeudu TA, Eze UU et al. *In vivo* and *in vitro* efficacy of Albendazole against canine ancylostomosis: a possible presence of anthelmintic resistance in Nigerian local breed of dogs. Res J Parasitol. 2016;11(1–2):20–26.

Jimenez Castro PD, Howell SB, Schaefer JJ, Avramenko RW, Gilleard JS, Kaplan RM. Multiple drug resistance in the canine hookworm Ancylostoma caninum: an emerging threat? Parasit Vectors. 2019;12(1):576. https://doi.org/10.1186/s13071-019-3828-6

Jimenez Castro PD, Venkatesan A, Redman E et al. Multiple drug resistance in hookworms infecting greyhound dogs in the USA. Int J Parasitol Drugs Drug Resist. 2021;17:107–117. https://doi.org/10.1016/j.ijpddr.2021.08.005

Jimenez Castro PD, Durrence K, Durrence S et al. Multiple anthelmintic drug resistance in hookworms (Ancylostoma caninum) in a Labrador breeding and training kennel in Georgia, USA. J Am Vet Med Assoc. 2022;261(3):342–347. https://doi.org/10.2460/javma.22.08.0377

Kolapo TU, Hay A, Gesy KM et al. Canine Alveolar Echinococcosis: an emerging and costly introduced problem in North America. Trans and Emerg Dis. 2023;2023:1–10. https://doi.org/10.1155/2023/5224160

Leutenegger CM, Lozoya CE, Tereski J, Savard C, Ogeer J, Lallier R. Emergence of Ancylostoma caninum parasites with the benzimidazole resistance F167Y polymorphism in the US dog population. Int J Parasitol Drugs Drug Resist. 2023;21:131–140. https://doi.org/10.1016/j.ijpddr.2023.01.001

Leutenegger CM. Association of the novel benzimidazole resistance marker Q134H with F167Y in dogs with *Ancylostoma caninum*. Presented at the ACVIM Forum, Philadelphia, 15–17 June 2023a

Leutenegger CM. Frequency of intestinal parasites in dogs and cats identified by molecular diagnostics. Presented at the ACVIM Forum, Philadelphia, 15–17 June 2023b

Marsh AE, Babcock S. Legal implications of zoonotic disease transmission for veterinary practices. Vet Clin North Am Small Anim Pract. 2015;45(2):393–vii. https://doi.org/10.1016/j.cvsm.2014.11.008

Marsh AE, Lakritz J. Reflecting on the past and fast forwarding to present day anthelmintic resistant Ancylostoma caninum – a critical issue we neglected to forecast. Int J Parasitol Drugs Drug Resist. 2023;22:36–43. https://doi.org/10.1016/j.ijpddr.2023.04.003

Nezami R, Blanchard J, Godoy P. The canine hookworm *Ancylostoma caninum*: A novel threat for anthelmintic resistance in Canada. Can Vet J. 2023;64(4):372-378.

Tropical Council for Companion Animal Parasites (TroCCAP). Canine guidelines. 2023. https://www.troccap.com/canine-guidelines (last accesed 2 October 2023)

Venkatesan A, Jimenez Castro PD, Morosetti A et al. Molecular evidence of widespread benzimidazole drug resistance in Ancylostoma caninum from domestic dogs throughout the USA and discovery of a novel β-tubulin benzimidazole resistance mutation. PLoS Pathog. 2023;19(3):e1011146. https://doi.org/10.1371/journal.ppat.1011146

Weese S, Evason M. Infectious diseases of the dog and cat - a color handbook. Boca Raton:CRC Press; 2019