frontiers | Frontiers in Veterinary Science

TYPE Editorial
PUBLISHED 21 July 2023
DOI 10.3389/fvets.2023.1258004

OPEN ACCESS

EDITED AND REVIEWED BY
Yukifumi Nawa,
Khon Kaen University, Thailand

*CORRESPONDENCE
Ettore Napoli
✉ enapoli@unime.it

†These authors have contributed equally to this work

RECEIVED 13 July 2023
ACCEPTED 14 July 2023
PUBLISHED 21 July 2023

CITATION
Napoli E, D'Amico G and Ramos RAN (2023) Editorial: Dog filariosis: the threat walks not only in the blood stream.
Front. Vet. Sci. 10:1258004.
doi: 10.3389/fvets.2023.1258004

Editorial: Dog filariosis: the threat walks not only in the blood stream

Ettore Napoli[1*†], Gianluca D'Amico[2†] and Rafael Antonio Nascimento Ramos[3,4†]

[1]Department Veterinary Sciences, University of Messina, Messina, Italy, [2]Department of Parasitology and Parasitic Diseases, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania, [3]Laboratory of Parasitology, Federal University of the Agreste of Pernambuco, Garanhuns, Brazil, [4]Department of Veterinary Pathobiology, School of Veterinary Medicine and Biomedical Sciences, Texas A&M University, College Station, TX, United States

KEYWORDS

***Dirofilaria immitis*, *Dirofilaria repens*, *Acanthocheilonema reconditum*, *Cercopithifilaria* spp., epidemiology, canine heartworm disease**

Editorial on the Research Topic
Dog filariosis: the threat walks not only in the blood stream

The scientific literature on dog filariasis has expanded considerably in the last decade. From a search on the most used database, Pubmed (https://pubmed.ncbi.nlm.nih.gov/?term=dog$+$filariosis), 2,179 scientific articles were published between 1902 and 2022, of which 31.8% ($n = 693$) was produced the last decade (2012–2022). The question that arises is: what has led to this increased scientific production of *Canine filariasis*? *Canine filariasis*, or filarial nematode infection in dogs, may be caused by different species, including the most pathogenic *Dirofilaria immitis*. Other filarids characterized by microfilariae in the blood, such as *Dirofilaria repens* and *Acanthocheilonema reconditum*, are just as consequential due to potential zoonosis and species misdiagnosis. However, alluded to in the title of this article collection, "*The threat walks not only in the blood stream*"; not all filarid microfilariae dwell within the blood. Indeed, considerable attention has been drawn to the genera *Onchocerca* and *Cercopithifilaria*, whose microfilariae are skin-dwelling.

It is well-known that all nematodes of the Family Onchocercidae (Spirurida) are transmitted by arthropod vectors (e.g., *Dirofilaria* spp. by mosquitoes and *Cercopithifilaria* spp. by ticks) (1, 2), or there is strong evidence indicative to this type of transmission (e.g., *O. lupi*). From an epidemiological perspective, the vectorial transmission of pathogens has dramatically shifted due to the recent climatic changes that have influenced the distribution of arthropod populations (3). One of the consequences of global warming is the broadening area of colonization of arthropod vectors (e.g., mosquitoes, ticks, fleas), with the invasion of new areas and eventually increase of their vector capacity. For example, this spreading has been clearly observed for *D. immitis* and *D. repens* in Europe (2, 4, 5). In the past, *D. immitis* was considered endemic only in the Mediterranean countries. However, the distribution patterns have recently changed and expanded toward eastern and north-eastern European countries (6–8). Following the same trend, *D. repens* has increased its prevalence in areas where it has already been reported, and its distribution range has expanded into new areas of Europe, with new cases in both dog and human hosts (9).

Dirofilaria immitis, the main representant of this genus, has been reported to predominantly infecting dogs, other animal species (e.g., cats, wild canids, badger), and humans (5, 10, 11). In dogs, adult nematodes localize primarily in the pulmonary arteries, causing a severe and debilitating cardio-pulmonary condition known as "heartworm disease" (12). Females release first-stage larvae (microfilariae) in the bloodstream of the vertebrate host. Mosquito vectors (e.g., *Culex*, *Aedes*, *Ochlerotatus*, and *Anopheles*) ingest these microfilariae and develop for ∼14 days to become infective third-stage larvae (13). The success of larval development within the mosquito host depends on temperature (14). Thus, development ceases if the temperature falls below the minimum threshold (14°C). The total amount of environmental heat required for developing *D. immitis* can be expressed in degree-days above the threshold temperature (Heartworm Developing Units, HDU). In general, the transmission model assumes that an accumulation of 130 HDUs within a maximum period of 30 days (average life span of the mosquito host) is needed for *D. immitis* to reach infectivity (15).

D. repens has also been considered a notable mosquito-borne nematode, responsible for canine subcutaneous filariasis in dogs and sporadically in humans (16, 17). Adult nematodes are mainly found in the subcutaneous or intramuscular connective tissue of vertebrate hosts (2); however, the presence of this nematode has been recently reported in unusual anatomical locations such as the pelvic and mesentery cavity, eyes, and testis (18–21). Similar to *D. immitis*, the causative agent of subcutaneous dirofilariosis is transmitted by mosquitoes (e.g., *Aedes* and *Culex*) (22, 23). In several vertebrate hosts, including humans, most inoculated microfilariae die or migrate in host tissues originating from subcutaneous nodules (23, 24). These lesions are characterized by focal edema and erythema triggered by the presence of the parasite (25–28).

Although *Dirofilaria* species have been widely studied, other filarial nematodes are known to parasitize dogs, such as *O. lupi* (29–31). This nematode is an emergent species infecting domestic dogs and has been identified in Europe, the Middle East and North America (32–39). This parasite's infection in canids is characterized by the presence of ocular lesions, including subconjunctival granulomas (33, 40, 41). There are many gaps in the epidemiology of *O. lupi*, mainly because information about its vector is incomplete (42). Until recently, only *Simulium tribulatum* was suggested as the putative vector of this filarial worm in California, United States (US) (43).

Currently, three species of *Cercopithifilaria* have been recognized in dogs: *Cercopithifilaria grassii*, *Cercopithifilaria bainae*, and *Cercopithifilaria* sp. II (44–46). *C. bainae*, the most studied species within this genus, was first described in a dog from Brazil (45) and, in the last decade, was reported to infect dogs in Italy (46). Current evidence supports a broader distribution of *C. bainae* than previously known (29, 47–49). Unlike most filarioid species, *C. bainae* is vectored by *R. sanguineus* sensu lato (s.l) ticks (47, 50). Although its pathogenicity had not been fully elucidated, parasitism by this nematode has been associated with polyarthritis (51), dermatitis (29, 52), and the presence of a giant cutaneous cyst in dogs (53). The importance of other filarioid genera, such as *Acanthocheilonema* and *Brugia,* must be addressed. Despite low pathogenic relevance, *Acanthocheilonema* spp. may cause misdiagnosis in regions where *Dirofilaria* spp. are also endemic, and *Brugia* spp. has significant zoonotic implications (53).

In this Research Topic, the importance of canine filariasis have been demonstrated in five unique articles. Two literature reviews highlight the importance of cutaneous filarioids in the US (Gruntmeir et al.) and the other focus on *Dirofilaria* in the UK (Panarese et al.). Two research articles related to the risk of infection (Ciuca et al.) and new distribution patterns of *Dirofilaria* species in Italy (Napoli et al.), and finally, the evidence of the putative role of biting midges as vectors of *O. lupi* in the US (Roe et al.). This Research Topic will highlight significant aspects of canine filariasis to serve as a knowledge resource for any remaining gaps in the scientific literature that require attention.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Acknowledgments

The authors would like to thank Matthew Kulpa (Texas A&M University) for his suggestions in this manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Brianti E, Gaglio G, Napoli E, Giannetto S, Dantas-Torres F, Bain O, et al. New insights into the ecology and biology of *Acanthocheilonema reconditum* (Grassi, 1889) causing canine subcutaneous filariosis. *Parasitology.* (2012) 139:530–6. doi: 10.1017/S0031182011002198

2. Capelli G, Genchi C, Baneth G, Bourdeau P, Brianti E, Cardoso L, et al. Recent advances on *Dirofilaria repens* in dogs and humans in Europe. *Parasit Vectors.* (2018) 11:663. doi: 10.1186/s13071-018-3205-x

3. Caminade C, McIntyre KM, Jones AE. Impact of recent and future climate change on vector-borne diseases. *Ann N Y Acad Sci USA*. (2019) 1436:157–73. doi: 10.1111/nyas.13950

4. Brianti E, Panarese R, Napoli E, De Benedetto G, Gaglio G, Bezerra-Santos MA, et al. *Dirofilaria immitis* infection in the Pelagie archipelago: the southernmost hyperendemic focus in Europe. *Transbound Emerg Dis.* (2022) 69:1274–80. doi: 10.1111/tbed.14089

5. Mendoza-Roldan JA, Gabrielli S, Cascio A, Manoj RRS, Bezerra-Santos MA, Benelli G, et al. Zoonotic *Dirofilaria immitis* and *Dirofilaria repens* infection in humans and an integrative approach to the diagnosis. *Acta Trop.* (2021) 223:106083. doi: 10.1016/j.actatropica.2021.106083

6. Genchi C, Rinaldi L, Mortarino M, Genchi M, Cringoli G. Climate and *Dirofilaria* infection in Europe. *Vet Parasitol.* (2009) 163:286–92. doi: 10.1016/j.vetpar.2009.03.026

7. Széll Z, Bacsadi Á, Szeredi L, Nemes C, Fézer B, Bakcsa E, et al. Rapid spread and emergence of heartworm resulting from climate and climate-driven ecological changes in Hungary. *Vet Parasitol.* (2020) 280:109067. doi: 10.1016/j.vetpar.2020.109067

8. Fuehrer HP, Morelli S, Unterköfler MS, Bajer A, Bakran-Lebl K, Dwuznik-Szarek D, et al. *Dirofilaria* spp. and *Angiostrongylus vasorum*: current risk of spreading in Central and Northern Europe. *Pathogens.* (2021) 10:1268. doi: 10.3390/pathogens10101268

9. Otranto D, Dantas-Torres F, Brianti E, Traversa D, PetricetriGenchi C, et al. Vector-borne helminths of dogs and humans. *Parasit Vect.* (2013) 6:16. doi: 10.1186/1756-3305-6-16

10. Ionică AM, Deak G, Boncea R, Gherman CM, Mihalca AD. The European badger as a new host for *Dirofilaria immitis* and an update on the distribution of the heartworm in wild carnivores from Romania. *Pathogens.* (2022) 11:420. doi: 10.3390/pathogens11040420

11. Adagra C, Squires R, Adagra A, Elliman J, Constantinoiu C. Prevalence of infection with *Dirofilaria immitis* in cats in Townsville, Australia. *Vet Parasitol Reg Stud Rep*. (2021) 24:100580. doi: 10.1016/j.vprsr.2021.100580

12. McCall JW, Varloud M, Hodgkins E, Mansour A, DiCosty U, McCall S, et al. Shifting the paradigm in *Dirofilaria immitis* prevention: blocking transmission from mosquitoes to dogs using repellents/insecticides and macrocyclic lactone prevention as part of a multimodal approach. *Parasit Vectors.* (2017) 10:525. doi: 10.1186/s13071-017-2438-4

13. Silaghi C, Beck R, Capelli G, Montarsi F, Mathis A. Development of *Dirofilaria immitis* and *Dirofilaria repens* in *Aedes japonicus* and *Aedes geniculatus*. *Parasit Vectors.* (2017) 10:94. doi: 10.1186/s13071-017-2015-x

14. Ledesma N, Harrington L. Fine-scale temperature fluctuation and modulation of *Dirofilaria immitis* larval development in *Aedes aegypti*. *Vet Parasitol.* (2015) 209:93–100. doi: 10.1016/j.vetpar.2015.02.003

15. Cuervo PF, Fantozzi MC, Di Cataldo S, Cringoli G, Mera YSR, Rinaldi L. Analysis of climate and extrinsic incubation of *Dirofilaria immitis* in southern South America. *Geospat Health*. (2013) 8:175–81. doi: 10.4081/gh.2013.64

16. Gabrielli S, Mangano V, Furzi F, Oliva A, Vita S, Poscia R, et al. Molecular identification of new cases of human dirofilariosis (*Dirofilaria repens*) in Italy. *Pathogens.* (2021) 10:251. doi: 10.3390/pathogens10020251

17. Pampiglione S, Rivasi F. Human dirofilariasis due to *Dirofilaria* (*Nochtiella*) *repens*: an update of world literature from 1995 to 2000. *Parassitologia.* (2000) 42:231–54.

18. Napoli E, Bono V, Gaglio G, Giannetto S, Zanghdue to cia R, et al. Molecular identification o*Dirofilaria repens* (Spirurida: Onchocercidae) infection in the testicle of a dog. *Comp Immunol Microbiol Infect Dis.* (2019) 66:101326. doi: 10.1016/j.cimid.2019.06.007

19. Omeragić J, Beck R, Klarić D, Bačić E. *Dirofilaria repens* in canine testicles in Bosnia and Herzegovina. *Veterinaria.* (2018) 67:37–40.

20. Ravindran R, Julie B, Swapna SA, Jerin F, Jyothimol G, Lenka DR, et al. *Dirofilaria repens* in scrotum of dogs. *Trop Biomed*. (2016) 33:842–6.

21. Demiaszkiewicz AW, Karamon J, Jasik A. Case of *Dirofilaria repens* in a testis of a dog. *Med Weter*. (2013) 69:124–7.

22. Genchi C, Kramer LH. The prevalence of *Dirofilaria immitis* and *D. repens* in the old world. *Vet Parasitol.* (2020) 280:108995. doi: 10.1016/j.vetpar.2019.108995

23. Otranto D, Giannelli A, Latrofa MS, Dantas-Torres F, Trumble NS, Chavkin M, et al. Canine infections with *Onchocerca lupi* nematodes, United States, 2011-2014. *Emerg Infect Dis.* (2015) 21:868–71. doi: 10.3201/eid2105.141812

24. Pampiglione S, Fioravanti ML, Piccolotti D, Pizzicannella G, Reale D. Human dirofilariasis in Italy: a new case in the spermatic cord. *Parassitologia.* (2002) 44:93–6.

25. Agapito D, Aziz NA, Wang T, Morgan ER, Wright I. Subconjunctival *Dirofilaria repens* infection in a dog resident in the UK. *J Small Anim Pract.* (2018) 59:50–2. doi: 10.1111/jsap.12795

26. Hermosilla C, Pantchev N, Dyachenko V, Gutmann M, Bauer C. First autochthonous case of canine ocular *Dirofilaria repens* in Germany. *Vet Rec.* (2006) 158:134–5. doi: 10.1136/vr.158.4.134

27. Mircean M, Ionică AM, Mircean V, Györke A, Codea AR, Tăbăran FA, et al. Clinical and pathological effects of *Dirofilaria repens* and *Dirofilaria immitis* in a dog with a natural co-infection. *Parasitol Int.* (2017) 66:331–4. doi: 10.1016/j.parint.2017.02.003

28. Otranto D, Testini G, Dantas-Torres F, Latrofa MS, De Paiva Diniz PPV, De Caprariis D, et al. Diagnosis of canine vector-borne diseases in young dogs: a longitudinal study. *J Clin Microbiol.* (2010) 48:3316–24. doi: 10.1128/JCM.00379-10

29. Otranto D, Brianti E, Abramo F, Gaglio G, Napoli E, Latrofa MS, et al. Cutaneous distribution and localization of *Cercopithifilaria* sp. microfilariae in dogs. *Vet Parasitol.* (2012) 190:143–50. doi: 10.1016/j.vetpar.2012.05.016

30. Ramos RA, Giannelli A, Lia RP, Brianti E, Tarallo VD, Breitshwerdt EB, et al. Incidence of *Cercopithifilaria bainae* in dogs and probability of co-infection with other tick-borne pathogens. *PLoS ONE.* (2014) 9:e88198. doi: 10.1371/journal.pone.0088198

31. Mutafchiev Y, Dantas-Torres F, Giannelli A, Abramo F, Papadopoulos E, Cardoso L, et al. Redescription of *Onchocerca lupi* (Spirurida: Onchocercidae) with histopathological observations. *Parasit Vect.* (2013) 6:309. doi: 10.1186/1756-3305-6-309

32. Széll Z, Erdélyi I, Sréter T, Albert M, Varga I. Canine ocular onchocercosis in Hungary. *Vet Parasitol.* (2001) 97:243 doi: 10.1186/1756-3305-6-309logical o

33. Komnenou A, Eberhard ML, Kaldrymidou E, Tsalie E, Dessiris A. Subconjunctival filariasis due to *Onchocerca* sp. in dogs: report of 23 cases in Greece. *Vet Ophthalmol.* (2002) 5:119–26. doi: 10.1046/j.1463-5224.2002.00235.x

34. Hermosilla C, Hetzel U, Bausch M, GreE, Tsalie E, Dessiris A. Subconjunctival filariasis due to ption of ation of vector*Vet Rec.* (2005) 156:450–2. doi: 10.1136/vr.156.14.450

35. Faísca P, Morales-Hojas R, Alves M, Gomes J, Botelho M, Melo M, et al. A case of canine ocular onchocercosis in Portugal. *Vet Ophthalmol.* (2010) 13:117–21. doi: 10.1111/j.1463-5224.2010.00763.x

36. Labelle AL, Daniels JB, Dix M, Labelle P. *Onchocerca lupi* causing ocular disease in two cats. *Vet Ophthalmol.* (2011) 14:105–10. doi: 10.1111/j.1463-5224.2011.00911.x

37. Otranto D, Dantas-Torres F, Giannelli A, Latrofa MS, Papadopoulos E, Cardoso L, et al. Zoonotic *Onchocerca lupi* infection in dogs, Greece and Portugal, 2011-2012. *Emerg Infect Dis.* (2013) 19:2000–3. doi: 10.3201/eid1912.130264

38. Verocai GG, Sobotyk C, Lamison A, Borst MM, Edwards EE. Autochthonous, zoonotic *Onchocerca lupi* in a South Texas dog, United States. *Parasit Vect.* (2021) 14:203. doi: 10.1186/s13071-021-04707-4

39. McGarry JW, Carrozza R, Bradley C, Latrofa MS, Makepeace BL, Otranto D. *Onchocerca lupi* in imported dogs in the UK: implications for animal and public health. *BMC Vet Res.* (2022) 18:66. doi: 10.1186/s12917-022-03169-9

40. Sréter T, Széll Z. Onchocercosis: a newly recognized disease in dogs. *Vet Parasitol.* (2008) 151:1–13. doi: 10.1016/j.vetpar.2007.09.008

41. Komnenou AT, Thomas AL, Papadopoulos E, Koutinas AF. Intraocular localization of *Onchocerca lupi* adult worm in a dog with anterior uveitis: a case report. *Vet Ophthalmol.* (2016) 19:245–9. doi: 10.1111/vop.12277

42. Latrofa MS, Annoscia G, Colella V, Cavalera MA, Maia C, Martin C, et al. A real-time PCR tool for the surveillance of zoonotic *Onchocerca lupi* in dogs, cats and potential vectors. *PLoS Negl Trop Dis.* (2018) 12:e0006402. doi: 10.1371/journal.pntd.0006402

43. Hassan HK, Bolcen S, Kubofcik J, Nutman TB, Eberhard ML, Middleton K, et al. Isolation of *Onchocerca lupi* in dogs and black flies, California, USA. *Emerg Infect Dis.* (2015) 21:789–96. doi: 10.3201/eid2105.142011

44. Noè G. Contribuzioni alla sistematica e alla anatomia del genereFilaria. *La Filaria grassii*. (1907) 236–52.

45. Gouvea de Almeida GL, Vicente J. *Cercopithifilaria bainae* sp. n. parasita de *Canis familiaris* (L.) (Nematoda, Filarioidea). *Atas Soc Biol Rio de Janeiro*. (1985) 24.

46. Otranto D, Brianti E, Dantas-Torres F, Weigl S, Latrofa MS, Gaglio G, et al. Morphological and molecular data on the dermal microfilariae of a species of *Cercopithifilaria* from a dog in Sicily. *Vet Parasitol.* (2011) 182:221–9. doi: 10.1016/j.vetpar.2011.05.043

47. Latrofa MS, Dantas-Torres F, Giannelli A, Otranto D. Molecular detection of tick-borne pathogens in *Rhipicephalus sanguineus* group ticks. *Ticks Tick Borne Dis.* (2014) 5:943–6. doi: 10.1016/j.ttbdis.2014.07.014

48. Lineberry MW, Sundstrom KD, Little SE, Stayton EM, Allen KE. Detection of *Cercopithifilaria bainae* infection in shelter dogs and ticks in Oklahoma, USA. *Parasit Vect.* (2020) 13:216. doi: 10.1186/s13071-020-04089-z

49. Sazmand A, Bahiraei Z, Nemati F, Annoscia G, Bezerra-Santos MA, Nayebzadeh H, et al. Dermal microfilariae of dogs, jackals and cats in different regions of Iran. *Parasit Vect.* (2022) 15:28. doi: 10.1186/s13071-021-05141-2

50. Ramos RA, Giannelli A, Brianti E, Annoscia G, Cantacessi C, Dantas-Torres F, et al. Tick vectors of *Cercopithifilaria bainae* in dogs: *Rhipicephalus sanguineus sensu lato* versus *Ixodes ricinus*. *Parasitol Res.* (2013) 112:3013–7. doi: 10.1007/s00436-013-3474-4

51. Gabrielli S, Giannelli A, Brianti E, Dantas-Torres F, Bufalini M, Fraulo M, et al. Chronic polyarthritis associated to *Cercopithifilaria bainae* infection in a dog. *Vet Parasitol.* (2014) 205:401–4. doi: 10.1016/j.vetpar.2014.06.027

52. Soares RL, Parolin LB, Mateus NLF, de Figueiredo GRD, Rodrigues VR, de Oliveira GG, et al. Giant cutaneous cyst in a dog infected by *Cercopithifilaria bainae*. *Vet Parasitol Reg Stud Rep*. (2020) 20:100401. doi: 10.1016/j.vprsr.2020.100401

53. Chirayath D, Alex PC, Pillai UN, George S, Ajithkumar S, Panicker VP. Identification of *Brugia malayi* in dogs in Kerala, India. *Trop Biomed.* (2017) 34:804–14.