

Vector-borne zoonotic pathogens in cats

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Cats and dogs are the most popular pets. However, pets can transmit various pathogens and their close proximity to humans may lead to human infections – zoonoses. Transmission of zoonotic pathogens occurs through direct human-animal contact and/or arthropod vectors, such as ticks, fleas, mosquitoes, etc. The emergence of vector-borne zoonotic diseases may occur through international movement of owners with companion animals, which could be infected with pathogens and through spreading and subsequent establishment of disease vectors from endemic to non-endemic areas. The complex ecology of vector-borne zoonotic infections poses both a challenge to and opportunities for surveillance and control. Rising occurrence of vector-borne zoonotic diseases, their relevance to human health, and the relative lack of scientific researches related to feline VBDs point to the necessity to summarize and systemize information on the prevalence of agents of these diseases in populations of domestic cats. This review describes the main vector-borne zoonotic diseases in cats and provides an overview of the main pathogens isolated from cats, which have the potential to cause diseases in cats and humans.

Keywords: Cats, vector-borne zoonotic diseases, pathogens

INTRODUCTION

As a result of climate change, vector-borne zoonotic diseases (VBZDs) have become more common in the world, not only in humans, but also in dogs and cats (Bergmann, Hartmann, 2017). These infections may be transmitted from pets to humans or by vectors – ticks, fleas, lice, and mosquitoes. Cats, especially those with an outdoor lifestyle, are highly likely to be exposed to these arthropods (Otranto et al., 2017; Morganti et al., 2019).

According to the data for 2017 provided by the German statistical agency Statista Research Department, over the past decade, the cat popula-

tion in Europe increased to approximately 102.7 million in 2017 (Statista, 2019). As cats become one of the most popular choices of pets in Europe, it is important to analyse the rates of their VBZD infection. Although cats may act as carriers of the causative agents of diseases and/or infected arthropods to humans and other pets that share the domestic habitat, in Europe the epidemiology of feline vector-borne zoonotic pathogens (Fe-VBZPs) is generally less investigated in cats than in dogs (Otranto, Dantas-Torres, 2010; Chomel, Sun, 2011; Morganti et al., 2019). Cats appear to be less frequently infected and affected by vector-borne diseases than dogs. This impression is supported by the relative lack of scientific researches related to feline VBDs comparing to the number

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of publications about dogs. One of the reasons of the difference in the prevalence of canine and feline vector-borne diseases is that cats have natural resistance to the arthropods and the pathogens they transmit (Wikel, 2013; Kazimirova, Stibraniova, 2013; Day, 2016). Another reason is veterinary attention. Cats are less commonly taken to veterinary practitioners, so the diseases are less frequently detected and identified in cats than in dogs. In addition, the research community that focuses on feline VBDs is smaller and less funded, so there is less research material on this subject. All

the above-mentioned factors may be the reason for a smaller amount of knowledge about feline VBDs (Day, 2016).

There are many infectious agents of clinical importance to cats and some also have the potential for zoonotic significance to people (Table). Domestic cats (*Felis catus*) may be infected and transmit such intestinal parasites and vector-borne pathogens as bacteria, protozoa, and helminths. Some of these may be pathogenic not only to cats, but also have a potential threat to human health (Persichetti et al., 2016; Ot-ranto et al., 2017).

Table. Pathogenic infections in domestic cats

Infection	Causative agent	Hosts	Prevalence in domestic cats	Vectors	Geographic distribution	Clinical signs for domestic cats
Bartonellosis	<i>Bartonella henselae</i> , <i>B. clarridgeiae</i> , <i>B. quintana</i> , <i>B. oehlaria</i>	Many animals, dogs, cats, humans	Common	Fleas, ticks sus- pected	Worldwide	Subclinical
Toxoplasmosis	<i>Toxoplasma gondii</i>	Many animals, dogs, birds, cats, humans	Common	–	Worldwide	Subclinical – se- vere
Haemo- tropic Mycoplasma	<i>Candidatus Myco- plasma haemominu- tum</i> , <i>C. M. turicensis</i> , <i>M. haemofelis</i>	Cats, suscepti- ble to humans	Common	Fleas and ticks sus- pected	Worldwide	Subclinical
Dirofilariosis	<i>Dirofilaria immitis</i> , <i>D. repens</i>	Dogs, cats, foxes, humans	Relatively common	Mosqui- toes	Southern and parts of central Europe,	Subclinical – se- vere
Babesiosis	<i>Babesia canis</i>	Dogs, cats, humans	Uncommon (mostly in South Africa)	Ticks	Europe up to distribution of vector	Moderate – severe
Rickettsiosis	<i>Rickettsia felis</i> ,	Dogs, cats	Relatively common	Ticks and fleas	Worldwide	Subclinical
Anaplasmosis	<i>Anaplasma phagocyto- phylum</i>	Many animals, dogs, cats, humans	Less common	Ticks	Europe	Mild and sub- clinical infection
Leishmaniosis	<i>Leishmania infantum</i>	Dogs, cats, foxes, hares, humans, other animals	Less common	<i>Phle- botomine</i> sand-flies	Southern Europe	Subclinical
Borreliosis	<i>Borrelia burgdorferi</i> complex	Many animals, dogs, cats, humans	Rare	Ticks	Europe	Mostly subclinical

Stray cat populations are important as a public health threat and a source of zoonotic diseases, lacking the necessary preventative care for the control and monitoring of the distribution of zoonotic vector-borne infections (Möstl et al., 2013). Stray cats or cats with outdoor access often have high prevalence rates for most of the infectious agents associated with direct contact with other cats (Ravicini et al., 2016).

Increasing incidence of vector-borne zoonotic diseases, their relevance to human health, and a relative lack of scientific researches into feline VBDs show a necessity for summarised and systemised information on the prevalence of the agents of these diseases in populations of domestic cats. This review describes the main vector-borne zoonotic diseases in cats and provides an overview of the main pathogens isolated from cats, which have the potential to cause diseases in cats and humans.

Bacterial pathogens

One of the most common VBZDs in cats is **bartonellosis**. Cats are the main reservoirs of *Bartonella henselae*, *B. clarridgeiae*, *B. koehlerae*, and *B. quintana*. *B. henselae* and *B. clarridgeiae* are the causative agents of cat scratch disease (CSD) in humans (Debre et al., 1950; Pennisi et al., 2013). Most cats infected with *Bartonella* spp. bacteria are asymptomatic beyond possible fever, swollen glands and some muscle aches. This bacterium is naturally transmitted among cats by cat fleas (*Ctenocephalides felis*) or by flea faeces. Also, few studies have shown that *Ixodes ricinus* is a competent vector for *B. henselae* and that ticks may play a role in *Bartonella* spp. pathogen transmission (Eskow et al., 2001; Halos et al., 2005; Cotte et al., 2008). In North America, seroprevalence of *B. henselae* in the cat population ranges from 14 to 93% (Nutter et al., 2004; Case et al., 2006), with significantly higher seroprevalence detected in strays or cats with outdoor access (Nutter et al., 2004). In Europe, *Bartonella* spp. seroprevalence rates are also high in cats, ranging from 0% in Norway (Bergh et al., 2002) to 71.4% in Spain (Solano-Gallego et al., 2006). The percentage is higher in European Mediter-

ranean countries, where humidity and temperature are favourable for tick and flea infestations (Chomel et al., 2006). Animal-to-animal and animal-to-human pathogen transmission may occur during an animal bite, by exposure of an open wound, from a scratch or a bite, or bacteria-contaminated faeces. Vectors acquire bacteria from previous bloodmeal from an infected pet. CSD symptoms in humans are non-specific, may include fever, headaches, and enlargement of regional lymph nodes (McElroy et al., 2010). Atypical infection complications include retinitis, encephalitis, and endocarditis in 5–15% of CSD-infected humans (Chomel et al., 2004). *Bartonella* laboratory testing is required especially for pet cats owned by immunosuppressed persons as the bacteria are opportunistic, or when *Bartonella*-related disease is diagnosed in a individuals that live with cats or have contact with them (Pennisi et al., 2013). For pathogen-affected humans, there is usually a history of being scratched or bitten by a cat. For many patients its typical characteristic is a characteristic small, reddish, rounded bump on the site of the scratch or bite (Chomel et al., 2004). More specific testing may be required to isolate and identify the causative bacteria species as the pathogenicity of them differs. The polymerase chain reaction (PCR) is the most advanced method for detecting and identifying bacterial DNA, which may be done by taking a sample of blood or tissue from the infected patient. However, tests do not always confirm bartonellosis as a cause of the disease, since the bacteria are not constantly circulating through the blood stream. Multiple tests may be needed in order to ascertain the presence of the *Bartonella* spp. bacteria (Para et al., 2017).

Mycoplasmas are pathogenic gram-negative bacteria that parasites animals and humans. Quite recently, the zoonotic importance of feline haemoplasmas was pointed out (Tasker et al., 2018). The haemoplasmas are haemotropic bacteria that parasite red blood cells and can induce haemolytic anaemia (Barker, Tasker, 2013). The three main haemoplasma species known to infect cats are *Mycoplasma haemofelis*, *Candidatus Mycoplasma haemominutum*,

and *Candidatus Mycoplasma turicensis*. These mycoplasmas have a worldwide distribution, although their prevalence varies geographically. The prevalence of the bacteria has been estimated among cats, and the infection rate appears to be 4.9 to 23.3% (reviewed by Tasker et al., 2018). In general, *Candidatus M. haemominutum* is most prevalent in domestic cats (0–46.7% of cats found to be infected); it is followed by *M. haemofelis* (0–46.6% of cats), and *Candidatus M. turicensis* (0–26.0% of cats) (reviewed by Tasker, 2010). The actual prevalence of infection is not calculated because the infections are not always detectable (Jensen et al., 2001). Feline haemoplasma infections are usually more common in male nonpedigree cats with outdoor access and in cat bite abscesses (Tasker et al., 2018). *M. haemofelis* in cats can cause an acute haemolytic anaemia, either directly or by initiating immune-mediated destruction of red blood cells; it might also trigger the suicidal death of infected erythrocytes (Felder et al., 2011). A wide range of clinical signs, including anaemia, pyrexia, lethargy, and splenomegaly characterises the disease, which may result in death if left untreated. Based on the polymerase chain reaction (PCR) testing, 20% to as many as 40% of anaemic and/or sick cats are infected with *M. haemofelis* (Jensen et al., 2001; Criado-Fornelio et al., 2003). In most veterinary clinics, the identification of *Mycoplasma* spp. in cats is based on the microscopic analysis of blood smear. However, in cases of low parasitaemia and due to the morphological similarity between the species, the microscopic analysis of haemoplasma is complicated and could lead to incorrect diagnosis (Aklilu et al., 2016). The use of molecular techniques is necessary to effectively detect and identify *Mycoplasma* species.

First described as a human pathogen in 1991, *Rickettsia felis* is an emerging insect-borne pathogen and the causative agent of flea-borne spotted fever (Brown, Macaluso, 2016). The worldwide distribution of this pathogen follows the distribution of cat fleas (*Ctenocephalides felis*)– the primary vector and reservoir of *R. felis* (Parola, 2011). In Europe, seropositivity of cat fleas for *R. felis* is about 26%, according to a study

conducted in Italy (Giudice et al., 2014). *Rickettsia* can be transmitted via a flea bite or when a wound is contaminated with flea faeces left on the skin. After inoculation of the parasite in cats, these proteobacteria infest red blood cells and may cause immune-mediated thrombocytopenia. A small percentage of infected animals may develop flue-like symptoms, such as fever. Although serious illness rarely occurs in felines, there is a zoonotic potential as the bacteria can be spread to other animals or humans causing serious disease. Other species of *Rickettsia* may also infect domestic cats. *R. typhi*, which is primarily found in dogs and wild animals, can also occur in felines infested with infected canine fleas (Reif, Macaluso, 2009). Seropositivity for *R. typhi* is about 15.8% as investigated in Spain (Nogueras et al., 2013). The use of molecular tools, specifically the PCR, to detect pathogens from around the globe has confirmed *R. felis* infections from every continent except Antarctica (Parola, 2011).

Anaplasmosis is a vector-borne disease caused by gram-negative bacterium *Anaplasma phagocytophilum*. Bacteria transmit via a bite of an infected *Ixodes* spp. tick; approximately 24–48 hours of tick attachment are needed for pathogen transmission to an animal (Day et al., 2016; Duplan et al., 2018). Infections are usually reported in late spring, the most active period of ticks. In the United States, the prevalence of *A. phagocytophilum* exposure in feral cats is approaching 10% (Galemore et al., 2018). In Europe, Aguirre et al. (2004) tested 122 blood samples from cats from Madrid and the presence of antibodies of these bacteria was observed in three (4.9%) specimens. Infected animals may show vague symptoms of lethargy, anorexia, and fever (Little, 2010). Cases of anaemia, neutrophilia and lymphopenia caused by this pathogen have also been recorded. Clinical signs of an infected pet are non-specific and can be intermittent, so accurate diagnosis of anaplasmosis is challenging (Savidge et al., 2016). This pathogen should be included on veterinary diagnosis list for any domestic cat living in an *Ixodes* spp. endemic area with potential exposure to arthropods (Woldehiwet, 2010).

Lyme disease is known to be one of the most common vector-borne diseases in the world. It is caused by the spirochete species of *Borrelia burgdorferi* bacteria group (Littman et al., 2018). The pathogen is transmitted by ticks; the vector has to be attached to the victim for about a day for the pathogen to transmit. It is quite an uncommon infection for domestic cats, although in some cases it may manifest itself in lameness of a cat due to inflammation of the joints, lack of appetite, and lethargy. Also, some cats may develop more clinically severe symptoms such as kidney, heart, and nervous system diseases (Krupka, Straubinger, 2010). Domestic cats living in the endemic areas of *Borrelia* spp. have been shown to be seropositive for this pathogen. A hypothesis exists that cats may fail to develop borreliosis because they are more efficient at removing infected tick than dogs (Burgess, 1992). Currently there is not enough data about borreliosis in cats to thoroughly analyse the cause and clinical significance of this infection (Littman et al., 2018).

Protozoan pathogens

Toxoplasmosis is a zoonotic disease with the causative agent *Toxoplasma gondii*. This protozoan parasite has a worldwide distribution, infects all species of animals and birds, and usually causes an asymptomatic disease in humans (Gross, 1996). Felines are the definitive host and the only animals capable of shedding oocyst with their faeces. As it is one of the most common infectious diseases in the world, from 30 to 50% of the human population is infected with this pathogen (Flegr et al., 2014). Seroprevalence of *T. gondii* antibodies in the cat populations in Europe vary from 50 to up to 80% (Barros et al., 2018). It is important for cat owners to be aware of the pathogen infection rates during travel to the areas of high prevalence. However, toxoplasmosis does not have any specific symptoms: it may manifest as neurological or flu-like symptoms and that is why it is difficult to estimate the infection rate in the cat population (Flegr et al., 2014). Serology indicates a high global prevalence of infection in cats, however, toxoplasmosis with clinical

symptoms in cats is a rare occurrence. Nevertheless, parenteral inoculation with even a few *T. gondii* oocysts can kill the animal. New-born kittens can die from acute toxoplasmosis despite receiving passively transferred antibodies from the mother (Dubey et al., 1988). Monitoring of toxoplasmosis infection in cat populations will allow better prediction of future levels of human infection with this important zoonotic disease (Hill et al., 2014).

Leishmania is a zoonotic protozoan parasite transmitted by phlebotomine sand-flies between animals and from animals to humans (Baneth et al., 2016). Usually these flies occur across tropical and subtropical regions, with several species found in Europe. In recent years the range of phlebotomine sand-flies and their transmitted *Leishmania* spp. has increased. *Leishmania* species endemic in Europe is *L. infantum* (Baneth et al., 2016). Vectors transmit *Leishmania* pathogens via bites. Felines can be infected with several *Leishmania* species – *L. infantum* (most pathogenic), *L. mexicana*, *L. braziliensis*, *L. amazonensis*, and *L. venezuelensis*. However, domestic cats are still regarded as an unusual host for this pathogen, although the first case of feline leishmaniosis was recorded in 1912 (Pennisi, 2002). Only few cases of feline leishmaniosis have been reported worldwide, some of them in Europe: France (Pennisi, 2002), Italy (Pennisi, 2002), Portugal (Costa Durao et al., 1994), Spain (Portus et al., 2002), and Switzerland (Rüfenacht et al., 2005). Feline leishmaniosis may occur in two types: as a skin or the most severe form, abdominal reaction, also known as black fever. Affected cats in the USA are frequently found to have acquired the *Leishmania* infection in another country, especially the Mediterranean basin, Portugal and Spain (Pennisi, 2002).

Babesiosis is an emerging globally distributed zoonotic disease (Baneth et al., 2004). As a vector-borne infection transmitted by ticks babesiosis poses a serious threat to human and animal health. Several *Babesia* spp. species have been documented in domestic cats worldwide. Babesiosis is less common in domestic cats and has mostly been reported in

South Africa, infections mainly due to *Babesia felis*, protozoan piroplasm that may cause anaemia and icterus. *B. cati*, generally found in India, is less pathogenic. *B. leo*, which is genetically similar to *B. felis*, is common in South African lions but may also be prevalent in domestic cats of this area (Penzhorn et al., 2004). Occasional cases of canine *Babesia* spp. infections in domestic cats have been reported in Europe, for example *B. canis* in Spain and Portugal, *B. canis*-like species in Poland, and *B. microti*-like species in Portugal. Feline babesiosis caused by other species than *B. felis* is usually less pathogenic and presents as a mild chronic disease. Commonly it may appear as haemolytic anaemia with secondary signs such as anorexia, lethargy, and rough haircoat (Jacobson et al., 2000). In babesiosis treatment, accurate detection and species identification are the key elements for the correct therapy and the prediction of the course of the disease (Solano-Gallego, Baneth, 2011).

Vector-borne helminth parasites

Dirofilaria parasites are the most important filarial worms causing heartworm disease (HWD) in dogs and subcutaneous dirofilariasis. Of this genus, *D. immitis* and *D. repens* are the main species causing these diseases, *D. immitis* being more pathogenic. When present, most common symptoms of *D. immitis* infection in cats are cough, dyspnoea, vomiting, and diarrhoea, and weight loss may also be observed. Sudden death of a seemingly healthy pet is more usual in felines. *D. repens* causes subcutaneous dirofilariasis in cats; in cases of heavy infection and sensitised patients, pruritus, pustules, ulcerative lesions, and exfoliate dermatitis may be observed (Genchi et al., 2015). Filarial worms usually infect dogs, but there are reported cases of these pathogens in cats as well. Felines acquire the parasite after mosquitos ingest the parasite from infected dogs and while feeding on a cat. (Lee, Atkins, 2010). Compared to canines, cats are imperfect hosts for both species, as after inoculation only a small percentage of larvae develop to the adult stage. That is why many important

facts differ between parasite life cycle in felines and canines: the percentage of worms that reach sexual maturity (about 20% in cats and 75% in dogs), the size of the parasite (adult worms are smaller in cats), parasite life expectancy (about four years in cats and seven years in dogs), and the localization of the worm (ectopic is more frequent in felines than in dogs) (McCall et al., 2008; Simón et al., 2014). Infections in cats may be asymptomatic or show dramatic acute symptoms that may lead to animal death. Cat infections with *D. immitis* and *D. repens* have been reported in many European countries (Genchi et al., 2015). However, the true prevalence of feline HWD is difficult to evaluate due to diagnostic difficulties, but infection in felines is detected in the same areas as canine HWD, which vary from 9 to 18% in unprotected dogs (Venco et al., 2011; Genchi et al., 2015). Information about the prevalence of *D. repens* in cats in Europe is also limited: the few studies performed in the continent show 1.6% prevalence rate in Italy and 0.7% prevalence rate in cats in central Poland (Traversa et al., 2010; Bajer et al., 2016). Because of the epidemiology of the disease, every cat living in the area where dogs are infected with *Dirofilaria* spp., should be considered at risk of infection.

CONCLUSIONS

The present review provides summarized information on the prevalence of selected vector-borne zoonotic pathogens in cats and shows that domestic cats are vulnerable to several infectious agents that may also cause significant danger to humans (e.g. *Bartonella* spp., *Mycoplasma* spp., *Rickettsia* spp., *Anaplasma phagocytophilum*, *Borrelia* spp., *Toxoplasma gondii*, *Leishmania* spp., *Babesia* spp., *Dirofilaria* spp.). This review also points to the necessity for continuous development of molecular investigation methods for better and more sufficient diagnosis of the causative agents of these infections. Due to the difficulties in finding sufficient indicative clinical signs in most cases of above-mentioned feline

infections, it is important to have additional information about the distribution of possible pathogens not only in Europe, but also worldwide. Although typically pets do not transmit vector-borne diseases to people directly, they bring the vectors of zoonotic diseases to close proximity to people, potentially increasing the risk of a disease. Therefore, studies in feline vector-borne zoonotic diseases that quantify diseases risks attributable to pets need more attention.

Received 1 June 2019

Accepted 1 July 2019

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KATĖSE APTINKAMŲ VEKTORIŲ PLATINAMI ZOONOTINIAI PATOGENAI

Santrauka

Katės ir šunys – dažniausiai namuose laikomi augintiniai. Dėl nuolatinio šeiminių kontaktų su augintiniais kasmet pasaulyje pasireiškia įvairios infekcijos – nuo lengvų alerginių reakcijų iki gyvybei pavojingų susirgimų, vadinamų zoonozėmis. Infekcinių ligų sukėlėjai perduodami žmogaus ir gyvūno tiesioginio kontakto metu ir / arba per nariuotakojus vektorius, pvz., erkes, blusas, uodus ir t. t. Viena iš priežasčių, lemiančių vektorių platinamų zoonozių plitimą pasaulyje, – šeiminių keliavimas su augintiniais, kurie gali būti užsikrėtę patogenais, ir jų vektorių platinimas iš endeminių į neendemines zonas. Didėjantis šių ligų paplitimas, jų svarba žmonių sveikatai ir santykinai mažas kiekis mokslinių tyrimų, susijusių su katėse aptinkamais vektorių platinamais zoonotiniais patogenais, rodo, kad būtina apibendrinti ir susisteminti informaciją apie šių ligų sukėlėjų paplitimą naminių kačių populiacijose. Šioje apžvalgoje apibūdinamos pagrindinės vektorių platinamos zoonozės ir apžvelgiami katėse aptinkami patogenai, galintys sukelti ligas žmonėms ir jų augintiniams.

Raktažodžiai: katės, vektorių platinamos zoonozės, patogenai