ON GUARD Dogs tend to be bitten by infected deer tick adults, which are most active in the cooler early spring and late fall. But there are no risk-free months, and year-long prevention practices are recommended.

PARASITOLOGY

Lyme Disease

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In the United States, Lyme disease is the most commonly diagnosed tick-borne disease of dogs and humans; the primary causative agent, *Borrelia burgdorferi* sensu stricto, is transmitted via the bite of an infected blacklegged tick (deer tick). The predominant vectors of *B. burgerdorferi* in the eastern half of the United States are *Ixodes scapularis* ticks, and on the Pacific coast of the United States they are *Ixodes pacificus* ticks. The pathogen is maintained in endemic areas through an enzootic cycle between wildlife reservoirs and *Ixodes* ticks. In highly endemic regions, more than 70% of local adult blacklegged ticks carry *B. burgdorferi*, posing a significant risk to both canine and public health. This article discusses the basic epidemiology, clinical presentation, diagnosis, treatment, and prevention of Lyme disease in dogs in the United States.

AGENT

The term "Lyme disease" refers to a general disease caused by multiple *Borrelia* species within the *B. burgdorferi* sensu lato group. In the United States, the most common species of *Borrelia* that causes Lyme disease in dogs and humans is *B. burgdorferi* sensu stricto, of which approximately 30 genotypes (i.e., strains) have been described on the basis of outer surface protein C (OspC) genotyping. Other *Borrelia* species found in the United States include *B. mayonii*, *B. bissetii*, *B. americana*, and *B. andersoni*; however, whether or how frequently these species cause Lyme disease in dogs is unknown. As such, the focus of this article is on *B. burgdorferi* sensu stricto (hereafter referred to simply as *B. burgdorferi*). This corkscrew-shaped, motile bacterium has a complicated lipoprotein surface coat that changes in a characteristic way through the pathogen's transmission cycle, enabling it to survive in the disparate environments of tick vector

FIGURE 1. Adult female *Ixodes scapularis* tick.

From top: Steven Ellingson\shutterstock.com; courtesy Dr. Michael Dryden.

and susceptible host species. Several of these temporally expressed surface lipoproteins are the foundation for *B. burgdorferi* diagnostic assays and vaccines.

TRANSMISSION

B. burgdorferi is transmitted through the bite of an infected *Ixodes* tick. In the United States, the primary tick vector of *B. burgdorferi* is *I. scapularis*, the blacklegged or deer tick (**FIGURE 1**). Over the past 20 years, the geographic distribution of *I. scapularis* ticks has more than doubled, and ticks of this species are now found throughout the eastern half of the United States (**FIGURE 2**).[1] Expansive white-tailed deer populations in this area provide an ample supply of hosts favored by adult *I. scapularis* ticks. However, although white-tailed deer support local *I. scapularis* tick populations, they do not serve as a transmission reservoir for *B. burgdorferi*. Lyme disease also occurs in the western United States, where the primary vector of *B. burgdorferi* is the *I. pacificus* tick.

B. burgdorferi is rarely (if ever) transmitted from an adult female tick to her offspring. Ticks most commonly become infected as juveniles after a bloodmeal on an infected wildlife host (most commonly rodents). Because ticks typically feed only one time per life stage, the next opportunity for *B. burgdorferi* transmission is during the next bloodmeal in the tick's next life stage.

Different life-stage *I. scapularis* ticks emerge at different times of the year (varies according to geographic location), giving a seasonality to Lyme disease transmission dynamics. Humans are often infected with *B. burgdorferi* in the summer because they are most likely to be infected by *I. scapularis* nymphs, which are

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active in the summer. Dogs tend to be bitten by infected *I. scapularis* adults, which are most active in the cooler early spring and late fall months. However, actively host-seeking *I. scapularis* adult ticks can be collected when temperatures drop to ~35°F,[2] a temperature frequently reached throughout winter. As such, for most states, there is no risk-free month for tick encounters, and dogs living in these states would benefit from year-long tick/tick-borne pathogen prevention practices.

PREVALENCE

In the United States, ~30,000 to 40,000 cases of human Lyme disease are reported to the Centers for Disease Control and Prevention each year,[3] and reported cases are estimated to represent only 10% of the actual number.[4] Most human Lyme disease cases are clustered in the New England, mid-Atlantic, and upper Midwest regions, where during 1993 to 2012, the number of high-risk counties increased by more than 300%.[5] Because of their close association, humans and dogs share many of the same risk factors for

FIGURE 2. Estimated distribution of *Ixodes scapularis* tick populations, United States.[3]

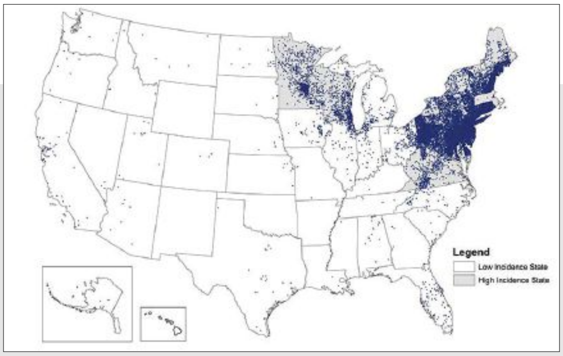

FIGURE 3. Reported cases of (human) Lyme disease, United States, 2018.[3]

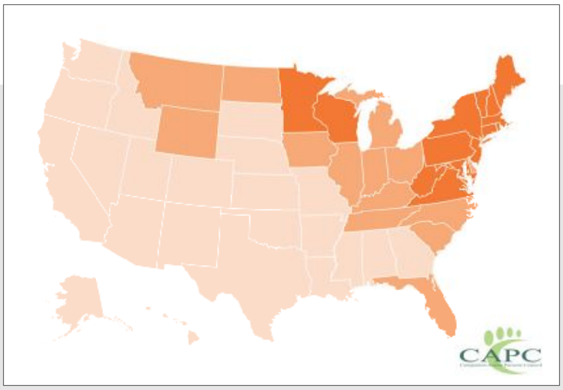

FIGURE 4. Seroprevalence of *Borellia burgdorferi* among dogs, United States, 2018. Of serologic diagnostic tests submitted in 2018, 5.64% (318,590/5,645,806) were positive for *B. burgdorferi*.[7]

Courtesy Companion Animal Parasite Council

encountering *B. burgdorferi*–infected ticks; thus, dogs serve as excellent sentinels for human Lyme disease risk.[6] This association is highlighted by comparing maps of Lyme disease cases for humans (**FIGURE 3**)[3] with maps of *B. burgdorferi* seroprevalence among dogs (**FIGURE 4**).[7]

As for humans, Lyme disease is the most commonly diagnosed tick-borne disease for dogs. Based on data collated by the Companion Animal Parasite Council (CAPC), ~5.09% (359,461/7,057,815) of canine serum samples submitted in 2019 were positive for *B. burgdorferi*.[7] CAPC estimates that the number of seropositive cases probably represents ~30% of total cases, suggesting that at least 1 million dogs in the United States are seropositive for *B. burgdorferi*. A recent study examining *B. burgdorferi* seroprevalence trends among dogs during 2010 to 2017 in the eastern United States demonstrated that seroprevalence is decreasing in several states (CT, DE, MA, MD, NH, NJ, RI, VA, and WI) while increasing in others (ME, NY, PA, IA, MI, NC, SC, and WV).[8] In states with a decreasing trend, seroprevalence still remained very high during the last year assessed (~5% to 19%). In comparison, states with an increasing trend (~1% to 14% during the last year assessed) tended to be geographically adjacent to states with decreasing seroprevalence, highlighting the expanding distribution and risk for Lyme disease to dogs in the United States. Although Lyme disease does occur in the southern and western United States, fewer cases are noted in these regions because of differences in tick behavior, which reduce human/pet tick encounters, and differences in available host species, some of which (e.g., western fence lizards) can rid the tick of *B. burgdorferi* infection. However, examination of *I. scapularis* genetic diversity in the eastern United States revealed north-to-south flow of *I. scapularis* tick populations, which could lead to an increased risk for Lyme disease in southern areas based on the behavioral differences of the northern *I. scapularis* tick populations.[9]

CLINICAL SIGNS

Clinical signs of Lyme disease do not develop in most dogs infected with *B. burgdorferi*, but subclinical polyarthritis or periarteritis may develop in these dogs.[10] In ~10% of infected dogs, clinical signs do develop; however, these signs are largely nonspecific (e.g., lethargy, malaise, shifting-leg lameness, anorexia, and depression). The signature bullseye rash common in humans with Lyme disease does not develop in dogs. In a subset of dogs, signs may progress to more chronic manifestations (e.g., frank arthritis and protein-losing nephropathy [Lyme nephritis]). Lyme nephritis is a rapidly progressive glomerulonephritis in dogs seropositive for *B. burgdorferi*; however, a direct causal link is still not fully understood. This condition has not been experimentally duplicated but is thought to be caused by deposition of antigen-associated immune complexes in the kidneys.[11] A retrospective study of 322,145 dogs found that risk for chronic kidney disease was increased by 43% in dogs with positive Lyme test results (IDEXX SNAP 3Dx, SNAP 4Dx, or SNAP 4Dx Plus; idexx.com).[12] Among dogs with protein-losing nephropathy, clinicopathologic findings for *B. burgdorferi*–seropositive dogs were distinct from those of seronegative dogs. Seropositive dogs were more likely to be a retriever or retriever-mix and to have thrombocytopenia, anemia or neutrophilia, biochemical evidence of azotemia, hyperkalemia and hyperphosphatemia, hematuria, glucosuria, urine culture–negative pyuria, and immune complex glomerulonephritis (indicated in renal biopsy samples).[13] Although that study found the aforementioned variables to be more common in dogs with protein-losing nephropathy and seropositivity for *B. burgdorferi*, additional studies (including experimental models) are needed to fully demonstrate direct causal relationships between *B. burgdorferi* infection and this condition.

It has been suggested that in dogs, neurologic manifestations and myocarditis may be associated with Lyme disease, but these manifestations are uncommon and poorly understood. In dogs co-infected with other tick-borne pathogens (e.g., *Anaplasma phagocytophilum* and *Babesi microti*, transmitted by the same tick vector), overall clinical signs can be worse and treatment complicated. Although cats in Lyme disease-endemic areas are commonly seropositive for *B. burgdorferi*, findings of associated clinical disease are rare or unclear. In cats experimentally infected with *B. burgdorferi*, no signs of clinical disease were observed;[14] however, some practitioners in highly Lyme disease–endemic areas report having seen cats displaying clinical signs of Lyme disease.[15,16]

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DIAGNOSTIC OPTIONS

Most commonly used to diagnose Lyme disease in dogs are the serologic assays. Although some laboratories still use traditional serologic methods (e.g., whole-cell enzyme-linked immunosorbent assay and immunofluorescence assay), these assays have largely been replaced by serologic assays that detect host antibodies to specific *B. burgdorferi* antigen proteins (e.g., IDEXX 4Dx Plus, AccuPlex 4 [Antech Diagnostics, antechdiagnostics.com], and VETSCAN Flex4 [Zoetis, zoetis.com]). These assays are qualitative, providing a yes/no answer regarding *B. burgdorferi* serostatus. IDEXX also offers a quantitative assay based on the C6 peptide antigen of the VlsE surface protein, which can be used to help determine active infection based on increasing, stable, or decreasing C6-specific antibody titers. The specific *B. burgdorferi* antigenic protein(s) around which diagnostic assays are developed is also a consideration because antigen choice affects assay specificity and sensitivity. Although these serologic assays detect presence of antibodies (not the pathogen), presence of antibodies against *B. burgdorferi* proteins does not necessarily indicate active infection but can also indicate previous infection (resolved naturally or through treatment) and maintenance of memory antibodies.

Diagnostic assays based on microscopic examination of thin blood smears to identify spirochetes and molecular assays looking for *B. burgdorferi* nucleic acid in blood samples are largely ineffective for diagnosing *B. burgdorferi* infection because this pathogen quickly leaves the bloodstream to sequester in other tissues. Observation of spirochetes on a thin blood smear is more likely to indicate a relapsing fever than Lyme disease.

TREATMENT

The antibiotics most frequently used to treat Lyme disease in dogs are doxycycline and minocycline, at a dosage of 10 mg/kg PO q12h to q24h for 30 days. The recent American College of Veterinary Internal Medicine consensus on Lyme borreliosis in dogs offers several other antibiotic treatment options.[17] In general, recovery prognosis for dogs that receive treatment for mild to moderate clinical Lyme disease is good. For dogs exhibiting clinical signs, including lameness, response to treatment is often demonstrated within the first few days. Because doxycycline and similar tetracycline antimicrobials are used to treat most tick-borne bacterial infections, clinical signs caused by co-infection of multiple tick-borne bacterial pathogens should respond as well. Successful infection control depends on client compliance (administration of the full antibiotic regimen). Although an empirical link between *B. burgdorferi* and glomerulonephritis has yet to be proven, the prognosis for dogs suspected of having Lyme nephritis is poorer, despite antibiotic intervention, especially if the nephritis is first observed during the latter stages of disease.

Treatment is generally recommended for seropositive dogs that display clinical signs of Lyme disease or are asymptomatic but have evidence of protein-losing nephropathy.[17] More controversial, however, is treatment for seropositive, nonclinical, nonproteinuric dogs. This decision ultimately lies between the client and veterinarian and should incorporate information based on the patient's history (e.g., first time seropositive versus history of being seropositive), geographic location and associated transmission risk, risk of developing chronic disease (e.g., breed considerations), potential for drug-associated adverse events, or concerns over judicious use of antibiotics (with regard to curbing antibiotic resistance).

Dogs in which infection naturally resolves or successfully responds to treatment will still maintain antibody levels for some time (several months to several years, depending on the specific antibody test). Neither previous *B. burgdorferi* exposure nor resolution of clinical Lyme disease (both of which would yield positive serostatus for at least several months) provides dogs with long-term protection against subsequent *B. burgdorferi* infection, especially against different *B. burgdorferi* strains. Therefore, use of tick-preventive products for seropositive dogs should continue and clients should make a risk-based decision about vaccinating dogs living in or visiting Lyme-endemic areas for further Lyme disease protection.

CONTROL AND PREVENTION

The best way to protect dogs from Lyme disease is to use tick-preventive products year-round. Several safe and effective commercial parasiticides are available for tick control on dogs and cats, including systemics (isoxazolines), topicals (permethrin, fipronil), and collars. Regardless of choice, clients should be encouraged to comply with manufacturer recommendations. For further protection of dogs living in or visiting Lyme-endemic areas, another effective strategy is vaccination. Several commercial Lyme vaccines for dogs are available. These vaccines consist of either bacterins (whole killed borreliae) or specific recombinant or chimeric outer surface proteins (e.g., OspA, OspC), with or without adjuvant. Vaccine-induced antibodies against OspA are thought to work by entering the tick during early stages of feeding and killing the borreliae inside the tick before they are transmitted to the dog. Vaccine-induced antibodies against OspC are thought to help kill or control borreliae during early infection in the dog around the tick bite site. However, because *Ixodes* ticks can carry other pathogens for which vaccines are not available, use of a vaccine in lieu of a tick-preventive product is not recommended. Risk-based decisions based on location, dog breed, travel, and veterinary consultation will help determine whether a dog would benefit from Lyme disease vaccination.

Other prevention strategies include reducing exposure to ticks and staying informed, or helping clients stay informed, about the risk for Lyme disease and other tick-borne diseases in local areas. Reducing exposure to ticks can include avoiding areas with ticks; however, doing so is not always practical or feasible since *B. burgdorferi*–infected ticks can be found in residential, recreational, and cosmopolitan areas. Reducing tick exposure on personal property can be achieved by creating a tick-safe zone through landscaping choices (e.g., maximizing sunlight exposure, minimizing presence of wildlife, and installing barriers between lawns and neighboring brushy/forested areas).

Client education about the risks of ticks and tick-borne pathogens in their local area can also be a very effective way to keep clients engaged in active tick-prevention strategies (e.g., use of tick-preventive products or Lyme vaccine). Provide clients with timely notice of region-specific data about ticks and tick-borne diseases (e.g., local CAPC seroprevalence data, whiteboards in clinic waiting rooms recording recent tick removals from pets, positive tick-borne disease serostatus tallies). Also useful is providing information or sources for additional local information on tick-borne diseases (e.g. state or county health department websites, university websites).

CONCLUSIONS

Lyme disease is a significant medical concern for canine and public health. Expanding geographic distributions of the tick vector increase the risk that dogs and humans will encounter *B. burgdorferi*–infected ticks. Effective measures for preventing Lyme disease in dogs include proper use of tick control products and risk-based use of Lyme vaccines. TVP

To see the references for this article, please visit **todaysveterinarypractice.com**.

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