Infections transmitted by ticks are increasingly recognized as important causes of disease in North American dogs.

Veterinarians have been combating canine bacterial and protozoal tick-borne diseases for decades (Table 1, page 56). In recent years, however, the geographic range of many of these pathogens has expanded, and several novel infections have been identified, suggesting that the full complement of pathogens transmitted by ticks is more extensive than currently recognized in many regions of North America.

All of these infections share a common link: tick transmission. As a result, tick control for dogs is more important than ever. Following is a brief review of diagnosis and treatment of the more common tick-borne infections in dogs, and a description of some newly recognized infections that may become important for canine health in the future.

**TICK-BORNE BACTERIAL DISEASES**

**Lyme Disease**

**Transmission.** *Borrelia burgdorferi* is the causative agent of Lyme disease in dogs and humans in the United States. Transmitted by *Ixodes* ticks, infection is most common in the Northeast, Midwest, and West Coast states. In recent years, geographic expansion of the *I scapularis*/*B burgdorferi* maintenance cycle has resulted in increasing reports of disease in new regions, including the Great Lakes states, Mid-Atlantic states, southern Appalachia, and southern Canada.1

**Presentation.** Clinical signs develop in a minority of infected dogs and include fever, lethargy, and shifting polyarthritis. In some cases, potentially fatal glomerulonephritis can develop.2

**Diagnosis.** Clinical disease, when present, usually develops several months after infection, and serologic testing is the preferred means of diagnosis. However, most seropositive dogs do not appear to develop clinical signs. Some serologic targets are highly specific for *B burgdorferi*, such as the C6 assay (SNAP 4Dx Plus and Lyme Quant C6 tests, idexx.com), while others, such as immunofluorescence antibody assays, may indicate past or current infection with several *Borrelia* species, complicating interpretation.3

**Prevention.** A combination of vaccination and diligent attention to tick control, with risk awareness supported by routine testing, can prevent Lyme disease, particularly in areas where infections are newly endemic.4

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How the C6 Peptide Detects Antibody

When *B burgdorferi* is transmitted to dogs in nature, the VlsE protein is expressed, resulting in production of antibodies that react to the C6 peptide. However, antibodies reactive to the C6 peptide are not produced following vaccination for Lyme disease, which provides a way to identify past or current infection in dogs. It is important to note that, even with this specific assay, a positive result indicates past or current infection with *B burgdorferi* but does not prove clinical disease.
Anaplasmosis

Transmission. Two *Anaplasma* species are known to cause disease in North American dogs:\(^5,6\)
- *A. phagocytophilum*: Ixodes ticks (*I. scapularis* and *I. pacificus*) are responsible for transmission, and *A. phagocytophilum* infections are most prevalent in the Northeast and upper Midwest.
- *A. platys*: *Rhipicephalus sanguineus* is considered this agent’s vector, and *A. platys* infection is seen throughout the U.S. but is most common in south central states, such as Texas and Oklahoma, likely due to higher populations of *R. sanguineus*.\(^1\)

Presentation. Clinical signs of anaplasmosis include fever, lethargy, anorexia, and lameness. Dogs with anaplasmosis often have thrombocytopenia, with low platelet counts more likely to be cyclical in *A. platys* infections. However, as with *B. burgdorferi*, many dogs may be clinically normal despite current infection.\(^5-7\)

Diagnosis. In clinically affected dogs, anaplasmosis is best diagnosed through a combination of polymerase chain reaction (PCR), serologic testing, and careful examination of stained blood smears (Table 2):\(^5,8\)
- PCR assays are most useful for identifying early, active infections prior to antibiotic treatment.
- Serologic testing is more likely to confirm established infections.

### TABLE 1.
**Common Canine Tick-Borne Disease Agents in North America**

<table>
<thead>
<tr>
<th>DISEASE DISEASE AGENTS</th>
<th>PRIMARY TICK VECTOR(S)</th>
<th>GEOGRAPHIC DISTRIBUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacterial Disease</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lyme borreliosis</td>
<td><em>Borrelia burgdorferi</em></td>
<td><em>Ixodes scapularis</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Ixodes pacificus</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Northeast, Midwest, and West Coast states; recent expansion in Mid-Atlantic states</td>
</tr>
<tr>
<td>Anaplasmosis</td>
<td><em>Anaplasma phagocytophilum</em></td>
<td><em>Ixodes scapularis</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Ixodes pacificus</em></td>
</tr>
<tr>
<td></td>
<td><em>Anaplasma platys</em></td>
<td><em>Rhipicephalus sanguineus</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>South central, southwestern U.S.; reported nationwide</td>
</tr>
<tr>
<td>Ehrlichiosis</td>
<td><em>Ehrlichia canis</em></td>
<td><em>Rhipicephalus sanguineus</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>South central, southwestern U.S.; reported nationwide</td>
</tr>
<tr>
<td></td>
<td><em>Ehrlichia ewingii</em></td>
<td><em>Amblyomma americanum</em></td>
</tr>
<tr>
<td></td>
<td><em>Ehrlichia chaffeensis</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Ehrlichia species</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Ehrlichia muris</em></td>
<td><em>Ixodes scapularis</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upper Midwest (Minnesota and Wisconsin)</td>
</tr>
<tr>
<td>Rocky Mountain spotted fever</td>
<td><em>Rickettsia rickettsii</em></td>
<td><em>Dermacentor variabilis</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Rhipicephalus sanguineus</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>South central, southwestern, and eastern U.S.; western mountain states</td>
</tr>
<tr>
<td><strong>Protozoal Disease</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Babesiosis</td>
<td><em>Babesia vogeli</em>(^#)</td>
<td><em>Rhipicephalus sanguineus</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>South central, eastern U.S.; reported nationwide</td>
</tr>
<tr>
<td></td>
<td><em>Babesia gibson</em>(^#)</td>
<td><em>Rhipicephalus sanguineus</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reported sporadically nationwide</td>
</tr>
<tr>
<td></td>
<td>Other <em>Babesia</em> species</td>
<td>Various tick species worldwide</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Occasionally reported</td>
</tr>
<tr>
<td>Hepatozoonosis</td>
<td><em>Hepatozoon americanum</em></td>
<td><em>Amblyomma maculatum</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>South central and southeastern U.S.</td>
</tr>
<tr>
<td></td>
<td><em>Hepatozoon canis</em></td>
<td><em>Rhipicephalus sanguineus</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reported sporadically nationwide</td>
</tr>
</tbody>
</table>

* Transmission cycle not yet confirmed in North America
\(^\#\) Also referred to as *B. canis vogeli*
\(^\dagger\) More commonly transmitted by dog bite in North America

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With anaplasmosis often have thrombocytopenia, with low platelet counts more likely to be cyclical in *A. platys* infections. However, as with *B. burgdorferi*, many dogs may be clinically normal despite current infection.\(^5-7\)

Diagnosis. In clinically affected dogs, anaplasmosis is best diagnosed through a combination of polymerase chain reaction (PCR), serologic testing, and careful examination of stained blood smears (Table 2):\(^5,8\)
- PCR assays are most useful for identifying early, active infections prior to antibiotic treatment.
- Serologic testing is more likely to confirm established infections.
• Antibodies can be detected in many dogs during both early and established acute disease.
• Identification of morulae on blood smears can be readily achieved in many patients, particularly during acute infection.

Ehrlichiosis

Transmission. Several different *Ehrlichia* species can infect dogs in the U.S., including *E. canis* (Figure 1), *E. ewingii*, *E. chaffeensis*, Panola Mountain *Ehrlichia* species, and *E. muris*. Different tick species are responsible for transmitting these *Ehrlichia* species, resulting in widespread distribution of infection.

Presentation. Common clinical abnormalities associated with acute ehrlichiosis include fever, lethargy, myalgia, anorexia, and thrombocytopenia; epistaxis and petechial and ecchymotic hemorrhages may be seen in severe cases of *E. canis*-induced ehrlichiosis, while lameness and polyarthritis are more commonly associated with *E. ewingii* infection. Some animals that become chronically infected with *E. canis* can develop pancytopenia, neurologic disease, bleeding diatheses, or ocular abnormalities, and fatalities are often reported. Many dogs, however, exhibit subclinical *Ehrlichia* species infections.

Diagnosis. As with anaplasmosis, diagnosis can be made through PCR, serologic testing, and examination of blood smears; concurrent use of 2 or more methods improves the likelihood of confirming a diagnosis.

### Table 2: Diagnostic Strategies for Tick-Borne Disease Agents

<table>
<thead>
<tr>
<th>Diagnostic Method</th>
<th>Benefits</th>
<th>Limitations</th>
</tr>
</thead>
</table>
| Blood smear evaluation | • Rapid, in-clinic assay  
• Visualization of organisms (if present) confirms presence of *Anaplasma* species, *Ehrlichia* species, and protozoal agents | • Slide scanning can be time-consuming  
• Diagnosis to species level may be difficult  
• Useful only for identifying infection with *Anaplasma* species, *Ehrlichia* species, and protozoal agents |
| Whole blood PCR | • Widely available through diagnostic laboratories  
• Sensitive for acute infections with well-characterized *Anaplasma* and *Ehrlichia* species before initiation of antibiotic treatment  
• Sensitive for identifying infection with *Babesia* and *Hepatozoon* species  
• Depending on assay design, may be more specific than serologic testing  
• Some assays may provide quantitative results | • In-clinic testing with same-day results not usually available  
• Some organisms (*Borrelia burgdorferi*, *Rickettsia* species) unlikely to be present in blood sample, despite presence of infection and clinical disease  
• Less reliable when very low circulating rickettsemia present (chronic infection) and after initiation of antibiotic treatment  
• May not identify presence of infection with novel disease agents  
• May lead to false-positive results due to presence of closely related agents |
| Serologic testing  | • In-clinic assays available for many agents  
• Depending on design, allows for detection of antibodies to several different agents with one assay  
• Panel assays often available from diagnostic laboratories  
• Some assays may provide quantitative results  
• Paired (acute and convalescent) samples collected 2–4 weeks apart can identify rising or falling titers and, thus, recent infection | • May be less useful in acute infections before seroconversion if only a single sample is evaluated  
• Antibodies persist for months to years after infection, which can confuse interpretation  
• Cross-reactivity common, particularly with immunofluorescence-based assays, including to nonpathogenic organisms |
Rocky Mountain Spotted Fever

**Transmission.** Rocky Mountain spotted fever—caused by *Rickettsia rickettsii*—is considered one of the most serious tick-borne diseases in the Americas due to its high fatality rate and rapid onset. Infection with *R. rickettsii* is most commonly transmitted by *Dermacentor variabilis* in eastern North America and *D. andersoni* in the Rocky Mountain states, but other tick species, including *R. sanguineus* and *Amblyomma* species, have been confirmed to also transmit infections in North, Central, and South America.12

**Presentation.** Clinical signs include rapid onset of fever, lethargy, and anorexia. Thrombocytopenia is often present, and some dogs may develop bleeding diatheses. Neurologic complications occur frequently. Clinical disease, although relatively uncommon, is associated with high fatality rates in both humans and dogs, particularly when treatment is delayed or withheld.13 Prompt, aggressive treatment can result in a rapid response, with resolution of clinical signs within a few days.

**Diagnosis.** Diagnosis can be confirmed with serologic testing, but treatment should be initiated upon suspicion of infection rather than upon diagnostic confirmation because:

- Many patients with acute infection and disease have not yet seroconverted
- PCR of whole blood is less likely to identify infection with *R. rickettsii* than with *Anaplasma* or *Ehrlichia* species.

When presenting and convalescent titers are compared, demonstration of a rising titer can be diagnostic. Serologic assays for *R. rickettsii* are not specific, and when tick infestations are common, many dogs will have antibodies reactive to *R. rickettsii* due to past infection with other, nonpathogenic *Rickettsia* species. Results of any diagnostic tests should always be interpreted together with clinical presentation.14

**TICK-BORNE PROTOZOAL DISEASES**

**Babesiosis**

**Transmission.** Many *Babesia* species cause disease in dogs worldwide. However, the 2 most commonly identified in North American dogs are:

- *B. vogeli* (formerly *B. canis vogeli*), transmitted by *R. sanguineus* (**Figure 2**)
- *B. gibsoni*, usually transmitted between dogs through contaminated blood during dog fighting; also transmitted by ticks (*Haemaphysalis* species) in other parts of the world, with *R. sanguineus* suspected, but not confirmed, to be involved in transmission.15

Infection with *B. vogeli* appears particularly common in the southern U.S., where *R. sanguineus* populations are intense; infections are often identified in kennels harboring infestations with brown dog ticks.16

**Presentation.** Dogs with clinical babesiosis present with anorexia, fever, and depression; hemolytic anemia and pale mucous membranes are common. Disease is considered more common following splenectomy.17 Infection with *B. gibsoni* is most commonly reported in American Staffordshire and American pit bull terriers.16

**Diagnosis.** Infection is usually diagnosed by careful examination of stained blood smears for characteristic large (*B. vogeli*) or small (*B. gibsoni*) piroplasms within red blood cells.15 Serologic testing and PCR are also widely available and can be helpful in identifying chronic and acute infections, respectively.

**Hepatozoonosis**

**Transmission.** The most common and severe cause of canine hepatozoonosis in the U.S. is *Hepatozoon americanum*, transmitted by *Amblyomma maculatum* primarily in southern states.18 In recent years, *H. canis* has also been identified in the U.S., although this *R. sanguineus*-transmitted pathogen is more common in dogs in South America, Europe, Africa, and Asia.

Rather than transmission by tick bite, hepatozoonosis agents infect dogs when they ingest a tick containing infective sporozoites during grooming, predation or, in the case of *H. americanum*, when cystozoites are ingested from tissues of rodents or rabbits that have ingested infected ticks.19
Presentation. Dogs with disease due to *H. americanum* usually present with fever, myalgia, muscle atrophy, and poor body condition. Profound neutrophilia is often present, and periosteal bone proliferation may occur.\(^{18}\) Without treatment, body condition continues to deteriorate and many affected dogs die or are euthanized.

Diagnosis. Disease is most commonly diagnosed by whole blood PCR, although gamonts are occasionally found on blood smears (Figure 3). Histologic examination of muscle biopsy specimens is more sensitive than whole blood PCR for diagnosing infection, but less commonly pursued due to the invasive nature of sample collection. Serologic assays to confirm *Hepatozoon* infection are not available.

NOVEL TICK-BORNE DISEASE AGENTS

A variety of novel pathogens transmitted by ticks have been described in North America in recent years:

- Canine, human, and tick infections with novel *Ehrlichia* species have been described\(^{9,10}\)
- Canine and human infections with spotted fever group *Rickettsia* species other than *R. rickettsii* have been reported\(^{14,20}\)
- Canine infections with previously unrecognized *Babesia* and *Hepatozoon* species have been identified\(^{17,21}\)
- Some data suggest that ticks may transmit other organisms, such as *Bartonella* species.\(^{22,23}\)

In addition, viral tick-borne pathogens have been increasingly identified in humans.\(^{24,25}\) Heartland virus and Bourbon virus are 2 examples of recently identified, apparently tick-transmitted pathogens in humans, although neither has yet been described in dogs.

TREATMENT OF TICK-BORNE DISEASES

When treating dogs suspected of having tick-borne disease:

1. Base the decision to treat primarily on your clinical judgment.
2. Use diagnostic results as an adjunct to clinical judgment, but not as the basis for administering or withholding treatment.
3. In dogs with moderate to severe clinical illness, do not:
   - Delay treatment while waiting for diagnostic test results
   - Withhold treatment if findings on serologic testing or PCR are negative
4. Do not delay treatment in dogs with clinical disease, particularly rickettsial infections; these patients may be serologically negative at initial presentation and PCR may fail to identify a novel disease agent, but delaying treatment can result in death.

Bacterial Disease

Treatment of choice for common bacterial tick-borne disease agents is *doxycycline*. Recommended regimens vary according to the specific target agents, but doxycycline at 10 mg/kg PO Q 24 H for 28 days is effective against *B. burgdorferi*, *Anaplasma* species, *Ehrlichia* species, and *R. rickettsii*.\(^{5,6,8}\)

Clinical improvement is typically evident within the first week of therapy.\(^{6,26}\) Dogs that do not respond to doxycycline should be carefully re-evaluated for additional etiologic agents.

Protozoal Disease

Treatment recommendations for canine babesiosis and hepatozoonosis vary depending on the specific agent responsible.

- Infections with large *Babesia* species, such as *B. vogeli*, can be treated with *imidocarb dipropionate*, 6 mg/kg IM, with the dose repeated in 14 days.
- Infections with small *Babesia* species, such as *B. gibsoni*, are generally more difficult to treat; a combination of atovaquone, 13 mg/kg PO Q 8 H for 10 days, and *azithromycin*, 10 mg/kg PO Q 24 H for 10 days, is recommended.\(^{27}\)

Hepatozoonosis due to *H. americanum* is particularly challenging to treat and requires either:\(^{18}\)

- *Ponazuril*, 10 mg/kg PO Q 12 H for 14 days or
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- Triple therapy for 14 days with (1) trimethoprim sulfamethoxazole, 15 mg/kg PO Q 12 H; (2) clindamycin, 10 mg/kg PO Q 8 H; and (3) pyrimethamine, 0.25 mg/kg PO Q 24 H. Regardless of initial therapy choice, dogs with American canine hepatozoonosis should be maintained long-term (2 years or more) on suppressive therapy with decoquinate, 10 to 20 mg/kg PO Q 12 H. Nonsteroidal anti-inflammatory drugs are also useful to improve clinical condition.

PCR = polymerase chain reaction

References


