

# Early identification of Lyme disease complications

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## ABSTRACT

Complications of Lyme disease including Lyme arthritis, Lyme carditis, and Lyme neuroborreliosis, typically occur during the early disseminated and late phases of the disease. Clinicians must maintain a high index of suspicion so they can recognize and treat complications promptly. Early treatment with appropriate antibiotics often leads to improved clinical outcomes.

**Keywords:** Lyme carditis, Lyme arthritis, Lyme neuroborreliosis, early disseminated Lyme disease, late Lyme disease, Lyme disease complications

## Learning objectives

- Describe the incidence of Lyme disease as well as common complications of untreated Lyme disease.
- Identify the common manifestations of Lyme carditis, Lyme arthritis, and Lyme neuroborreliosis.
- Describe the available diagnostic and treatment options.

In the United States, Lyme disease, a tick-borne illness, is most commonly caused by the spirochete bacteria *Borrelia burgdorferi*.<sup>1</sup> Although about 30,000 cases are reported each year in the United States, the actual incidence of Lyme disease is about 476,000 cases annually, with most cases occurring in the Northeast and upper Midwest.<sup>2</sup> A missed diagnosis of Lyme disease can lead to a variety of systemic complications and increase patient morbidity and mortality.

The incubation period of Lyme disease ranges from 3 to 30 days, with an average of 7 to 14 days.<sup>3</sup> Lyme disease is more common in males and typically follows a bimodal age distribution, occurring most commonly in children ages 5 to 9 years and adults ages 45 to 59 years.<sup>4</sup> The three stages of Lyme disease are early localized, early disseminated, and late disease.<sup>5</sup> In early localized disease, about 80% of patients will experience the classic erythema



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migrans rash, which is often described as a localized annular lesion with central clearing (**Figure 1**).<sup>6</sup> During early disseminated disease, the patient may experience a constellation of symptoms including fever, headaches, fatigue, myalgia, facial nerve palsies, and cardiac or neurologic complications (**Table 1**).<sup>1,5</sup>

If left untreated, Lyme disease can lead to a variety of different complications including Lyme arthritis, Lyme carditis, and Lyme neuroborreliosis. Up to 60% of patients with untreated early Lyme disease will develop Lyme arthritis.<sup>5</sup> Lyme arthritis typically is manifested during late disease and can occur weeks or even months after the initial tick bite.<sup>5</sup> Between 4% and 10% of patients with untreated Lyme disease will develop Lyme carditis, which is most commonly seen in patients ages 10 to 45 years.<sup>1,4</sup> Lyme neuroborreliosis is less common in the United States than in Europe, and about 11% of patients with Lyme infection present with neurologic symptoms.<sup>7</sup>

## LYME ARTHRITIS

Lyme arthritis is the most common complication of late Lyme disease and often presents as monoarthritis of the knee weeks or months after the initial tick bite.<sup>5</sup> It also can present as asymmetric oligoarthritis, most often of the large joints (**Table 2**). Lyme arthritis is caused by vascular damage, cytotoxic processes, proliferation of fibroblasts, and fibrosis in the joint in response to a proinflammatory

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### Key points

- Lyme arthritis is the most common complication of undiagnosed Lyme disease, often presenting as a monoarthritis.
- Lyme carditis can present with a variety of ECG changes but most commonly presents with AV block, which may vary between first-, second-, and third-degree AV block.
- Lyme neuroborreliosis is a rare complication of untreated Lyme disease, commonly presenting as an ischemic stroke.
- Maintain a high index of suspicion while gathering a thorough patient history to help in the early identification and treatment of Lyme disease.

**FIGURE 1.** Erythema migrans rashes on light and dark skin



Source: Centers for Disease Control and Prevention, top photo by Gary Wormser. [www.cdc.gov/lyme/signs\\_symptoms/rashes.html](http://www.cdc.gov/lyme/signs_symptoms/rashes.html).

immune response following the infection.<sup>8</sup> About 27% of patients diagnosed with Lyme disease present with arthritis.<sup>9</sup> Because Lyme carditis is another complication of late Lyme disease, patients with Lyme arthritis should be further evaluated with an ECG to rule out this potentially severe complication.<sup>5</sup>

Laboratory evaluation of the patient with Lyme arthritis should include enzyme-linked immunosorbent assay (ELISA) and Western Blot analysis. Immunoglobulin G (IgG) for *B. burgdorferi* is considered diagnostic for Lyme arthritis in patients presenting with monoarthritis or polyarthritis in an endemic area.<sup>5</sup> Additionally, patients with Lyme arthritis often have leukocytosis and elevated inflammatory markers such as erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP).<sup>5</sup> Culture of *B. burgdorferi* is difficult to obtain from synovial fluid samples; however, polymerase chain reaction (PCR) testing often is positive before the initiation of treatment with antibiotics despite not being available for routine clinical use.<sup>10</sup> Imaging findings, including those on radiograph, CT, and MRI, often are nonspecific. For these reasons, and because of the complexities involved with synovial fluid testing, a diagnosis of Lyme arthritis can be made from the clinical presentation as well as serologic test results.

Patients with suspected or confirmed Lyme arthritis should be treated with a 28-day course of antibiotics: first-line agents are amoxicillin, cefuroxime, and doxycycline.<sup>5</sup> In patients who have only moderate improvement of their symptoms after completing the course of antibiotic therapy, a second 28-day course of antibiotics is indicated. Consider IV antibiotic therapy for 28 days in patients who have no response to the initial course of antibiotics or whose symptoms worsen.<sup>5,10</sup>

Most patients improve after antibiotic treatment, but some may develop antibiotic-refractory Lyme arthritis (A-RLA). In patients with persistent joint pain despite treatment with antibiotics, synovial fluid can be evaluated for A-RLA via PCR testing, but this testing is not mandatory and clinical diagnosis can be used.<sup>5</sup> Patients with persistent symptoms or proliferative synovitis may need treatment with nonsteroidal anti-inflammatory drugs (NSAIDs) and/or immunosuppressive therapy.<sup>8</sup> Most commonly, A-RLA treatment is initiated with methotrexate and patients often are referred to a rheumatologist for further management.<sup>10</sup> Additionally, referral to physical therapy is appropriate in patients with A-RLA, and has been shown to have clinical benefit in patients with refractory symptoms.<sup>5</sup> Although intra-articular corticosteroid injections typically are not recommended, arthroscopic synovectomy can be considered.<sup>5,11</sup>

### LYME CARDITIS

Lyme carditis occurs as a result of invasion of the myocardium by *B. burgdorferi*. This leads to an excessive immune response and severe inflammation. Spirochetes further

**TABLE 1.** Common tickborne illnesses<sup>26-31</sup>

	Ehrlichiosis	Babesiosis	Rocky Mountain spotted fever	Anaplasmosis
<b>Incidence</b>	2,093	2,418	5,207	5,655
<b>Geographic location</b>	Most common in North Carolina, New York, Arkansas, and Missouri	Most common in Connecticut, Massachusetts, Minnesota, New Jersey, New York, Rhode Island, and Wisconsin	Most common in North Carolina, Oklahoma, Arkansas, Tennessee, and Missouri	Most common in the upper Midwest and the Northeast
<b>Signs and symptoms</b>	<ul style="list-style-type: none"> <li>• Fever</li> <li>• Chills</li> <li>• Rash</li> <li>• Headache</li> <li>• Myalgia</li> <li>• Confusion</li> </ul>	<ul style="list-style-type: none"> <li>• Fever</li> <li>• Chills</li> <li>• Myalgia</li> <li>• Fatigue</li> <li>• Splenomegaly</li> <li>• Hepatomegaly</li> </ul>	<ul style="list-style-type: none"> <li>• Fever</li> <li>• Headache</li> <li>• Myalgia</li> <li>• Periorbital edema</li> </ul> <p>Late symptoms:</p> <ul style="list-style-type: none"> <li>• Altered mental status</li> <li>• Acute respiratory distress syndrome</li> <li>• Multisystem organ failure</li> </ul>	<ul style="list-style-type: none"> <li>• Fever</li> <li>• Chills</li> <li>• Headache</li> <li>• Myalgia</li> <li>• Rigors</li> <li>• Leukopenia</li> <li>• Thrombocytopenia</li> <li>• Transaminitis</li> </ul>
<b>Rash</b>	More common in children. Red splotches or pinpoint dots 5 days after fever begins	Not typically present	<ul style="list-style-type: none"> <li>• Early rash: Maculopapular rash on the wrists, forearms, and ankles that spreads</li> <li>• Late rash: Petechial rash (sign of late and severe disease)</li> </ul>	Fewer than 10% of patients present with rash
<b>Diagnostic testing</b>	PCR, indirect immunofluorescence antibody (IFA), IgG	Babesia parasites present inside red blood cells	PCR, indirect IFA, IgG	<ul style="list-style-type: none"> <li>• Morulae seen in cytoplasm of granulocytes (low sensitivity)</li> <li>• PCR, indirect IFA, IgG</li> </ul>

infiltrate the connective tissue and collagen fibers in the heart. Lyme carditis can present with a constellation of symptoms including palpitations, syncope, chest pain, dyspnea, dizziness, and presyncope (Table 2).<sup>4,12</sup> The Suspicious Index in Lyme Carditis (SILC) is a proposed tool that clinicians can use to evaluate the probability that Lyme carditis is the cause of the patient's high-degree atrioventricular (AV) block, the most common ECG finding in patients with Lyme carditis.<sup>13</sup> The SILC can be used to evaluate a patient's likelihood of Lyme carditis based on several risk factors, such as presence of constitutional symptoms, outdoor activity/endemic area, male sex, history of tick bite, age under 50 years, and erythema migrans rash.<sup>14</sup> Patients with a low risk of Lyme carditis should undergo standard treatment of their AV block and those with intermediate or high scores should begin empiric treatment with IV antibiotics and undergo further serologic testing.<sup>15</sup>

Clinical evaluation of the patient with Lyme carditis often reveals AV block. The degree of AV block may vary between first, second, and third degree.<sup>15</sup> Although patients most commonly present with first-degree AV block, other ECG abnormalities have been reported including sick sinus syndrome, atrial fibrillation, tachycardia-bradycardia syndrome, bundle-branch blocks, and rarely,

sudden cardiac death.<sup>6,13</sup> In addition to ECG abnormalities, patients with Lyme carditis may develop cardiomyopathy or myocarditis.<sup>15</sup>

Hospitalization is required in patients experiencing second- or third-degree AV block because a temporary pacemaker may be needed.<sup>4</sup> Begin treatment of suspected Lyme carditis immediately; do not wait for serologic testing to confirm the diagnosis.<sup>6</sup> The patient should be treated with IV ceftriaxone and continued until the second- or third-degree AV block has been resolved and the PR interval has returned to less than 300 ms.<sup>1</sup> Avoid permanent pacemaker insertion in patients with Lyme carditis, because conduction abnormalities typically resolve with appropriate antibiotic treatment.

Following resolution of the high-degree AV block, the patient can be transitioned to oral antibiotics to complete a 21- to 28-day course.<sup>4</sup> First-line treatments for adults include doxycycline, amoxicillin, and cefuroxime. Amoxicillin is recommended for first-line use in children; doxycycline or cefuroxime may be used in those who are allergic to penicillin. Avoid doxycycline in pregnant or lactating patients and use amoxicillin as first-line therapy in these patients.<sup>4,6,16</sup> Following appropriate treatment of Lyme carditis, patients should undergo stress testing or repeat ECG to evaluate for complete resolution of AV block.<sup>15</sup>

**TABLE 2.** Lyme disease complications<sup>1,4-10,12,13,15,17-20</sup>

Complication	Common signs and symptoms	Diagnostic findings
Lyme arthritis	<ul style="list-style-type: none"> <li>• Monoarthritis or oligoarthritis</li> <li>• Knee most commonly affected</li> <li>• Limited range of motion</li> <li>• Asymmetric oligoarthritis</li> </ul>	<ul style="list-style-type: none"> <li>• Elevated CRP and ESR</li> <li>• Synovial fluid WBC count of 25,000 to 50,000 cells/mm<sup>3</sup></li> <li>• Positive PCR</li> </ul>
Lyme carditis	<ul style="list-style-type: none"> <li>• Palpitations</li> <li>• Syncope</li> <li>• Chest pain</li> <li>• Dyspnea</li> <li>• Dizziness</li> </ul>	<ul style="list-style-type: none"> <li>• Bradycardia</li> <li>• AV block on ECG</li> <li>• High SILC score</li> <li>• Positive PCR</li> </ul>
Lyme neuroborreliosis	<ul style="list-style-type: none"> <li>• Headache</li> <li>• Radiculitis</li> <li>• Cranial neuritis</li> <li>• Facial nerve palsy</li> <li>• Meningitis</li> <li>• Encephalitis</li> <li>• Fatigue</li> <li>• Difficulty concentrating</li> <li>• Abnormal cognition</li> </ul>	<ul style="list-style-type: none"> <li>• Parenchymal brain lesion on imaging</li> <li>• Ischemic stroke</li> <li>• CSF analysis with lymphocytic pleocytosis, elevated protein concentrations, and hypoglycorrhachia</li> </ul>

### LYME NEUROBORRELIOSIS

This is a rare complication of Lyme disease, thought to be caused when *B. burgdorferi* and debris from the spirochete come into contact with neural cells. This leads to a proinflammatory response and neurologic damage.<sup>17</sup> Lyme neuroborreliosis most commonly presents as ischemic stroke. Patients also may experience transient ischemic attack, intracranial hemorrhage, cerebral venous sinus thrombosis, or aneurysm. In addition to these, patients may have one or all components of Bannwarth syndrome, which include lymphocytic meningitis (characterized by lymphocytic pleocytosis in cerebrospinal [CSF] fluid), cranial neuritis, and radiculoneuritis.<sup>18,19</sup> Patients also may exhibit cranial nerve palsy, most commonly facial nerve palsy, encephalitis, or myelitis (Table 2).<sup>19</sup> Consider a diagnosis of Lyme neuroborreliosis in patients who experience cerebral vasculitis or ischemic stroke with no cardiovascular risk factors, who live in an endemic area, or who display neurologic symptoms with unknown cause.<sup>19</sup>

Evaluate patients via serologic testing as well as imaging of the brain, including CT and MRI, which is more sensitive. Lyme infection is a rare cause of stroke, thus screening for Lyme disease should not be performed in all patients with stroke. Rather, obtain a detailed history from the patient and evaluate risk factors for tickborne illness.<sup>19</sup> Use of PCR techniques does not signifi-

cantly increase identification of patients who are truly positive for Lyme neuroborreliosis.<sup>20</sup> Additionally, negative serology does not rule out neuroborreliosis, because some patients have negative serology but have antibodies to *B. burgdorferi* in CSF.<sup>19</sup> If the diagnosis is in question, consider further evaluation with CSF analysis and imaging with cerebral angiography or transcranial doppler. CSF analysis often reveals lymphocytic pleocytosis, elevated protein concentrations, and hypoglycorrhachia.<sup>19</sup> CSF culture for *B. burgdorferi* is not widely available and is only positive in about 10% of patients with Lyme neuroborreliosis.<sup>20</sup> Although brain biopsy provides a definitive diagnosis of CNS vasculitis, it often is avoided because of its invasive nature.<sup>7</sup>

In patients with suspected or confirmed Lyme neuroborreliosis, IV ceftriaxone is the preferred agent and should be dosed at 2 g/day. Guidelines vary widely about the length of treatment for Lyme neuroborreliosis; a course of 14 to 21 days is usually recommended.<sup>20</sup> Most patients will have significant improvement in their neurologic symptoms with a course of antibiotics; however, some may require corticosteroids or immunosuppressive therapy.<sup>7</sup>

### POST-TREATMENT LYME DISEASE SYNDROME

Post-treatment Lyme disease syndrome (PTLDS) is diagnosed in up to 20% of patients treated for Lyme disease.<sup>21</sup> PTLDS is a clinical diagnosis for a patient who experiences continued or relapsing symptoms for at least 6 months after being treated for Lyme disease. The most common symptoms are pain, fatigue, and/or difficulty thinking.<sup>22</sup> No specific testing exists for the diagnosis of PTLDS, so a clinical diagnosis excluding other causes is used. Treatment is supportive because no cure exists for PTLDS.<sup>23</sup> Most patients experience improvement in their symptoms over a period of months.<sup>22</sup>

### PROPHYLACTIC TREATMENT AND VACCINATION

In regions that are highly endemic for Lyme disease, prophylactic treatment with a single dose of doxycycline may be indicated following a tick bite if the patient meets the following five criteria:

- No contraindication to doxycycline
- The attached tick is identified as an *I. scapularis* tick
- The tick has been estimated to be attached for more than 36 hours
- Prophylaxis is initiated within 72 hours of tick removal
- The exposure occurred in a highly endemic area.<sup>24</sup>

Because preventing one case of Lyme disease would require prophylactically treating 50 patients who had a tick bite, prophylactic treatment should not be used in all patients and should strictly adhere to the five criteria mentioned. By following these guidelines, clinicians should be able to identify patients at highest risk for developing Lyme disease and complications from

undiagnosed Lyme disease.<sup>24</sup> Prophylaxis is recommended for patients who meet the above five criteria because the benefits of prophylaxis likely outweigh the risks. Adults should be treated with a single dose of doxycycline 200 mg, and children weighing less than 45 kg (99.2 lb) should receive 4.4 mg/kg in a single dose.<sup>11</sup>

Human trials are expected to start soon for a human monoclonal antibody developed for preexposure prophylaxis by the University of Massachusetts Medical School's MassBiologics.<sup>25</sup> No vaccines exist to prevent Lyme disease; however, studies are under way exploring their development. Valneva and Pfizer have a vaccine, VLA15, undergoing phase 2 human trials.<sup>26</sup>

## CONCLUSION

Clinicians must have a high index of suspicion to appropriately identify patients experiencing complications of Lyme disease. Obtain a thorough history from patients who live in or who have recently visited highly endemic areas. Obtain a detailed history from patients presenting with new-onset monoarthritis, new AV block, or Bannwarth syndrome. If the history provided elicits a high index of suspicion, begin immediate treatment for Lyme disease complications. **JAAPA**

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## REFERENCES

- Riaz S, Garel A, Subedi A, et al. Third-degree atrioventricular block as the initial presentation of Lyme disease. *Cureus*. 2020;12(8):e9574.
- Centers for Disease Control and Prevention. Lyme disease data and surveillance. [www.cdc.gov/lyme/datasurveillance/index.html](http://www.cdc.gov/lyme/datasurveillance/index.html). Accessed September 14, 2022.
- Centers for Disease Control and Prevention. Travel-related infectious diseases. Lyme disease. [wwwnc.cdc.gov/travel/yellowbook/2020/travel-related-infectious-diseases/lyme-disease](http://wwwnc.cdc.gov/travel/yellowbook/2020/travel-related-infectious-diseases/lyme-disease). Accessed September 14, 2022.
- Fuster LS, Gul EE, Baranchuk A. Electrocardiographic progression of acute Lyme disease. *Am J Emerg Med*. 2017;35(7):1040.e5-1040.e6.
- Long KC, Cohn KA. Lyme arthritis: an update for clinical practice. *Pediatr Emerg Care*. 2018;34(8):588-591.
- Cheung B, Lutwick L, Cheung M. Possible Lyme carditis with sick sinus syndrome. *IDCases*. 2020;20:e00761.
- Moreno Legast G, Schnider A, Nicastrò N. Ischemic stroke: do not forget Lyme neuroborreliosis. *Case Rep Neurol Med*. 2018;2018:1720725.
- Steere AC. Posttreatment Lyme disease syndromes: distinct pathogenesis caused by maladaptive host responses. *J Clin Invest*. 2020;130(5):2148-2151.
- Schwartz AM, Hinckley AF, Mead PS, et al. Surveillance for Lyme disease—United States, 2008–2015. *MMWR Surveill Summ*. 2017;66(22):1-12.
- Arvikar SL, Steere AC. Diagnosis and treatment of Lyme arthritis. *Infect Dis Clin North Am*. 2015;29(2):269-280.
- Centers for Disease Control and Prevention. Lyme disease prophylaxis after tick bite. [www.cdc.gov/ticks/tickbornediseases/tick-bite-prophylaxis.html](http://www.cdc.gov/ticks/tickbornediseases/tick-bite-prophylaxis.html). Accessed September 14, 2022.
- Gazendam N, Yeung C, Baranchuk A. Lyme carditis presenting as sick sinus syndrome. *J Electrocardiol*. 2020;59:65-67.
- Patel KP, Farjo PD, Juskowich JJ, et al. Early-onset Lyme carditis with concurrent disseminated erythema migrans. *Am J Cardiovasc Dis*. 2017;7(2):53-56.
- Besant G, Wan D, Yeung C, et al. Suspicious index in Lyme carditis: systematic review and proposed new risk score. *Clin Cardiol*. 2018;41(12):1611-1616.
- Kerndt CC, Bills JA, Shareef ZJ, et al. Early disseminated Lyme carditis inducing high-degree atrioventricular block. *Case Rep Cardiol*. 2020;5309285.
- Centers for Disease Control and Prevention. Lyme carditis treatment. [www.cdc.gov/lyme/treatment/lymecarditis.html](http://www.cdc.gov/lyme/treatment/lymecarditis.html). Accessed September 14, 2022.
- Garcia-Monco JC, Benach JL. Lyme neuroborreliosis: clinical outcomes, controversy, pathogenesis, and polymicrobial infections. *Ann Neurol*. 2019;85(1):21-31.
- Garkowski A, Zajkowska J, Zajkowska A, et al. Cerebrovascular manifestations of Lyme neuroborreliosis—a systematic review of published cases. *Front Neurol*. 2017;8:146.
- Shah A, O'Horo JC, Wilson JW, et al. An unusual cluster of neuroinvasive Lyme disease cases presenting with Bannwarth syndrome in the Midwest United States. *Open Forum Infect Dis*. 2017;5(1):ofx276.
- Centers for Disease Control and Prevention. Neurologic Lyme disease. [www.cdc.gov/lyme/treatment/neurologiclyme.html](http://www.cdc.gov/lyme/treatment/neurologiclyme.html). Accessed September 14, 2022.
- Geebelen L, Lernout T, Devleesschauwer B, et al. Non-specific symptoms and post-treatment Lyme disease syndrome in patients with Lyme borreliosis: a prospective cohort study in Belgium (2016–2020). *BMC Infect Dis*. 2022;22(1):756.
- Centers for Disease Control and Prevention. Post-treatment Lyme disease syndrome. [www.cdc.gov/lyme/postlds/index.html](http://www.cdc.gov/lyme/postlds/index.html). Accessed September 14, 2022.
- Bohe JR, Jutras BL, Horn EJ, et al. Recent progress in Lyme disease and remaining challenges. *Front Med (Lausanne)*. 2021;8:666554.
- Zhou G, Xu X, Zhang Y, et al. Antibiotic prophylaxis for prevention against Lyme disease following tick bite: an updated systematic review and meta-analysis. *BMC Infect Dis*. 2021;21(1):1141.
- Steere AC. Treatment of Lyme arthritis. *J Rheumatol*. 2019;46(8):871-873.
- Centers for Disease Control and Prevention. Lyme disease vaccine. [www.cdc.gov/lyme/prev/vaccine.html](http://www.cdc.gov/lyme/prev/vaccine.html). Accessed September 14, 2022.
- Centers for Disease Control and Prevention. Ehrlichiosis. [www.cdc.gov/ehrlichiosis/healthcare-providers/index.html](http://www.cdc.gov/ehrlichiosis/healthcare-providers/index.html). Accessed October 5, 2022.
- Centers for Disease Control and Prevention. Babesiosis. [www.cdc.gov/parasites/babesiosis](http://www.cdc.gov/parasites/babesiosis). Accessed October 5, 2022.
- Centers for Disease Control and Prevention. Hard tick relapsing fever. [www.cdc.gov/ticks/tickbornediseases/hard-tick-relapsing-fever.html](http://www.cdc.gov/ticks/tickbornediseases/hard-tick-relapsing-fever.html). Accessed October 5, 2022.
- Centers for Disease Control and Prevention. Rocky Mountain spotted fever. [www.cdc.gov/ticks/tickbornediseases/rmsf.html](http://www.cdc.gov/ticks/tickbornediseases/rmsf.html). Accessed October 5, 2022.
- Centers for Disease Control and Prevention. Anaplasmosis. [www.cdc.gov/ticks/tickbornediseases/anaplasmosis.html](http://www.cdc.gov/ticks/tickbornediseases/anaplasmosis.html). Accessed October 5, 2022.