Lyme disease is caused by bacteria that are transmitted to humans by hard-bodied ticks found in temperate climates throughout the world.1,2 In the United States, the disease is caused by Borrelia burgdorferi sensu stricto and is endemic in areas of the Northeastern and Middle Atlantic regions, as well as the upper Midwest and northern Pacific Coast (Figure 1). Ticks undergo a 3-stage life cycle during which they acquire the Lyme disease bacteria from mice and other rodent hosts and transmit them back to these hosts and to humans. The most common clinical manifestation is an expanding red rash called erythema migrans that occurs in ≈90% of cases (Figure 2). Other disease manifestations can be seen when the bacteria disseminate from the site of initial deposition in the skin to the heart and other organs. Before the discovery of effective antibiotic therapy, more than half of all Lyme disease patients experienced joint manifestations, whereas ≤10% had neurological or cardiac manifestations. The number of people experiencing these complications has decreased markedly since the use of standard antibiotic therapy early in the course of infection.

Lyme Carditis
Lyme carditis occurs when Lyme bacteria that have disseminated in the blood establish infection in heart tissue.3,4 Lyme carditis usually occurs in association with joint or nervous system manifestations, although the heart may be the only site of clinically apparent disease. Early studies revealed that carditis occurred in ≈4% to 10% of untreated Lyme disease patients, with a higher rate if asymptomatic carditis was included.3 Because of the use of antibiotic therapy early in infection, Lyme carditis is now considered an uncommon manifestation of Lyme disease in adults and a rare manifestation in children.3 Most cases of Lyme carditis occur between June and December, 4 days to as long as 7 months (median 21 days) after initial illness. There is a slight male predominance and two age peaks of 5 to 14 years and 44 to 59 years. It is unclear whether patients with underlying heart disease have an increased risk of cardiac involvement or complications from Lyme disease compared with the general population. Lyme carditis is much less common in Europe than in the United States, which may be because of differences in strains of Lyme disease bacteria in Europe and North America.

The Lyme bacterium can infect all parts of the heart, including the conduction system around the atrioventricular node, the outer or inner membranes of the heart, the cardiac muscle, and more rarely, cardiac blood vessels or heart valves.3,4 Tissue damage results primarily from inflammation that occurs as the host immune cells respond to bacteria that enter the tissue. The predominant cardiac manifestation is partial heart block caused by impairment of the electric signal that controls contraction of the upper and lower chambers of the heart. Heart block usually is mild, with complete resolution within 6 weeks after onset. The most common symptoms are light-headedness, fainting, shortness of breath, palpitations, and/or chest pain. Heart block occasionally is complete and permanent, requiring insertion of a pacemaker. Myocarditis or pericarditis may occur. Death has been reported in a few cases.

Diagnosis and Treatment of Lyme Disease
The Centers for Disease Control and Prevention has developed a case definition of Lyme disease that has been widely accepted as a way to standardize the clinical diagnosis. A person is considered to have Lyme disease if a physician diagnoses an erythema migrans rash that has attained a diameter of at least 5 cm (2.5 inches). In the absence of this rash, there must be at least 1 objective sign of involvement

From the Yale School of Public Health (P.J.K.) and the Yale School of Medicine (P.J.K., L.K.B.), New Haven, CT.
Correspondence to Peter J. Krause, MD, Senior Research Scientist, Yale School of Public Health, 60 College St, New Haven, CT 06520. E-mail peter.krause@yale.edu

(Circulation. 2013;127:e451-e454.)
© 2013 American Heart Association, Inc.
Circulation is available at http://circ.ahajournals.org

DOI: 10.1161/CIRCULATIONAHA.112.101485
of the musculoskeletal system (eg, joint swelling), nervous system (eg, meningitis and peripheral nerve abnormality), or cardiovascular system (eg, arrhythmia), in addition to a positive laboratory test result that supports *B burgdorferi* infection.

The Centers for Disease Control and Prevention’s case definition of Lyme disease was developed for surveillance purposes. In practice, the diagnosis of Lyme disease is based primarily on risk of exposure to infected ticks because of residence in or travel to a Lyme endemic area and the recognition of an erythema migrans rash (Figures 2 and 3), with or without a history of tick bite. The rash begins at the tick bite site and must enlarge to at least 2.5 inches in diameter to meet the case definition of Lyme disease and to distinguish it from a tick bite reaction. The primary rash (Figure 2) may increase to >10 inches, and multiple other lesions may develop (Figure 3) if left untreated. Standard antibiotic treatment kills the causative bacteria and leads to rapid resolution of the rash. If Lyme disease is suspected in a person with viral-like symptoms but without an erythema migrans rash, a Lyme antibody test should be obtained to provide laboratory support for the diagnosis. The DNA of the causative organism occasionally can be detected with a polymerase chain reaction test on specimens obtained from blood, joint fluid, or spinal fluid, but this test is not very sensitive for detection of the Lyme bacteria in clinical settings.

Lyme carditis should be considered in anyone suspected or confirmed to have Lyme disease who experiences cardiac symptoms. An ECG that demonstrates varying degrees of heart block supports the diagnosis of Lyme carditis. Other potentially useful tests include a chest radiograph, echocardiogram, magnetic resonance imaging, gallium scan, and (rarely) an endomyocardial biopsy, but findings are not specific for Lyme disease. Patients with Lyme carditis usually have a positive blood antibody test for Lyme disease. Carditis may resolve spontaneously, but standard antibiotic treatment can shorten disease duration and prevent complications (Table). For mild to moderate heart disease, amoxicillin or doxycycline is given by mouth for 14 to 21 days. Severe cardiac disease usually is treated with ceftriaxone or cefotaxime given by intravenous infusion over 14 to 21 days. Most cases resolve within 1 or 2 weeks. Longer courses of antibiotics have not been shown to be superior to the standard duration and incur increased risk of side effects, as well as added expense.
admission and continuous monitoring are advisable for patients with moderate to severe heart block, because the degree of block may fluctuate and worsen very rapidly in such patients. For some patients, hospital admission with temporary (or rarely, permanent) pacemaker placement is necessary, but the general prognosis for Lyme carditis is excellent.

**Prevention of Lyme Disease**

The risk of Lyme disease can be markedly reduced through personal protective measures that minimize contact with ticks.2,5 Ticks are most abundant in wooded or tall grassy areas and especially at the edge, where woodlands and meadows or lawns meet. These are areas where deer and mice (and the ticks that feed on them) abound. If travel through such areas cannot be avoided, wearing protective clothing can be helpful, such as a long-sleeve shirt tucked into long

Figure 2. Erythema migrans rash. This rash can be uniformly red (A) or have a bull’s-eye appearance with central clearing (B). The rash usually is painless but may be associated with slight tenderness, tingling, or itch. It may be accompanied by constitutional symptoms such as fever, headache, arthralgia, or myalgia. Photographs are courtesy of Vijay K. Sikand, MD, East Lyme, CT.

Figure 3. Disseminated erythema migrans rash. Approximately 15% of patients with erythema migrans rash have multiple lesions, as shown here. Satellite lesions are typically smaller than the primary lesion. Photograph is courtesy of Vijay K. Sikand, MD, East Lyme, CT.
Table. Recommended Antimicrobial Regimens for Treatment of Adults With Lyme Disease

<table>
<thead>
<tr>
<th>Drug</th>
<th>Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preferred oral regimens</strong></td>
<td></td>
</tr>
<tr>
<td>Amoxicillin</td>
<td>500 mg 3 times per day</td>
</tr>
<tr>
<td>Doxycycline</td>
<td>100 mg twice per day</td>
</tr>
<tr>
<td>Cefuroxime axetil</td>
<td>500 mg twice per day</td>
</tr>
<tr>
<td><strong>Alternative oral regimens</strong></td>
<td></td>
</tr>
<tr>
<td>Azithromycin</td>
<td>500 mg orally per day (for 7–10 days)</td>
</tr>
<tr>
<td>Clarithromycin</td>
<td>500 mg twice per day (if the patient is not pregnant)</td>
</tr>
<tr>
<td>Erythromycin</td>
<td>500 mg orally 4 times per day</td>
</tr>
<tr>
<td><strong>Preferred parenteral regimen</strong></td>
<td></td>
</tr>
<tr>
<td>Ceftriaxone</td>
<td>2 g IV once per day</td>
</tr>
<tr>
<td><strong>Alternative parenteral regimen</strong></td>
<td></td>
</tr>
<tr>
<td>Cefotaxime</td>
<td>2 g IV every 8 h*</td>
</tr>
<tr>
<td>Penicillin G</td>
<td>18 to 24 million U per day IV, divided every 4 h*</td>
</tr>
</tbody>
</table>

*All drugs are administered for 14 to 21 days unless specified otherwise.2

1. Dosage should be reduced for patients with impaired renal function.

Nymphal deer ticks are very small (about the size of the head of a pin), and thus, a careful check under bright lighting of the entire body is recommended. A tick may be recognized visually as a small round mass or dark spot on the skin, or detected by feeling a bump on the skin while taking a bath or shower.3 One dose of doxycycline (200 mg) given within 72 hours after tick attachment can prevent Lyme disease in ≈90% of cases. Because the Lyme disease bacteria is transmitted only after a tick is attached for at least 36 hours, and only a small minority (3%–4%) of people who remove a deer tick develop Lyme disease, antibiotic prophylaxis is only recommended for people who remove ticks that are attached for at least 36 hours. If the tick species or duration of attachment cannot be determined, persons who have removed attached ticks from themselves should be monitored closely for signs and symptoms of Lyme disease (and other tick-borne diseases) for up to a month. Those who develop a rash at the site of the tick bite, multiple skin lesions elsewhere, or a generalized nonspecific illness within this observation period should promptly seek medical attention.

Because personal protective measures will not guarantee prevention of Lyme disease in endemic areas, residential and community protective measures are often used to provide additional protection.3 Property measures that may be effective in decreasing the risk of Lyme disease include sealing stone walls where mice nest. Wooden, plastic, wire mesh, or electrical fencing that is at least 5 feet high can help keep deer off property. Other measures include mowing grass, removing leaf litter, and using plantings that do not attract deer. A list of such plantings can be obtained at local health departments and some nurseries. Spraying areas of high exposure once a year in the late spring or early summer with acaricidal formulations such as carbaryl, cyfluthrin, or deltamethrin is effective in reducing the tick population, especially when combined with other land management strategies. Community measures that impact many households in a region have been shown to be effective in reducing Lyme disease incidence but are more difficult to implement. Removal of deer or markedly reducing the size of the deer population to approximately <8 deer per square mile has been shown to dramatically reduce the number of ticks and the incidence of Lyme disease. Typical coastal towns in Connecticut have ≈30 to 60 deer per square mile. Feeding devices that apply acaricides to deer or mice also have been shown to be effective. Finally, public education about preventive measures is important in reducing the risk of Lyme disease.

**Acknowledgments**

The authors are grateful to Vijay K. Sikand, MD, East Lyme, CT, for providing the photographs for Figures 2 and 3.

**Sources of Funding**

This work was supported in part by the Gordon and Llura Gund Foundation (Dr Krause) and the Harold W. Jockers award (Dr Bockenstedt).

**Disclosures**

Drs Bockenstedt and Krause received National Institutes of Health funding to conduct Lyme disease diagnostic studies, in conjunction with L2 Diagnostics, Inc, New Haven, CT.

**References**


Lyme Disease and the Heart
Peter J. Krause and Linda K. Bockenstedt

Circulation. 2013;127:e451-e454
doi: 10.1161/CIRCULATIONAHA.112.101485

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/127/7/e451

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org/subscriptions/