Tick-Borne Pulmonary Disease*

Update on Diagnosis and Management

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Ticks are capable of transmitting viruses, bacteria, protozoa, and rickettsiae to man. Several of these tick-borne pathogens can lead to pulmonary disease. Characteristic clinical features, such as erythema migrans in Lyme disease, or spotted rash in a spotted fever group disease, may serve as important diagnostic clues. Successful management of tick-borne diseases depends on a high index of suspicion and recognition of their clinical features. Patients at risk for tick bites may be coinfected with two or more tick-borne pathogens. A Lyme vaccine has recently become available for use in the United States. Disease prevention depends on the avoidance of tick bites. When patients present with respiratory symptoms and a history of a recent tick bite or a characteristic skin rash, a differential diagnosis of a tick-borne pulmonary disease should be considered. Early diagnosis and appropriate antibiotic therapy for these disorders lead to greatly improved outcomes. ***(CHEST 1999; 116:222–230)***

Key words: Ehrlichia; Lyme; pulmonary; respiratory; tick; tularemia

Abbreviations: AV = atrioventricular; RMSF = Rocky Mountain spotted fever

In the United States and Europe, more vector-borne diseases are transmitted to humans by ticks than by any other agent.[1] In addition to neurotoxins, ticks can transmit bacteria, rickettsiae, spirochetes, viruses, and protozoa.[2] Some tick-borne diseases, such as Lyme disease[3,4] and ehrlichiosis, can cause severe or fatal illnesses.[5,6] Cardiopulmonary complications associated with tick-borne diseases are particularly serious and may be life-threatening.[5,7] If a patient presents with pulmonary symptoms and gives a history of a recent tick bite, a pulmonary complication caused by a tick-borne disease should be considered in the differential diagnosis (Table 1). When left undiagnosed or untreated, these disorders can be crippling or fatal.[5,7,8]

Many species of ticks that have been found over a very wide geographic distribution[9–11] may transmit diseases to humans (Table 2). Ticks are obligate blood-sucking arthropods (Figs 1 and 2) that transmit pathogens while feeding.[11] Large reservoirs of ticks feed on the rodents and small mammals that inhabit wooded areas, gardens, and parklands.[12,13] Nevertheless, outbreaks of tick-borne diseases are not confined to rural areas. Successful management of tick-borne diseases depends on a high index of suspicion and an awareness of their geographic epidemiology and clinical features.[3,8] Tick-borne diseases have protean manifestations. Patients at risk for tick bites may harbor two or more concurrent tick-borne infections.[14] The diagnosis of a tick-borne disease is most often based on a constellation of clinical signs and a history of outdoor pursuits, skin rash, or tick bites.[3,9,10]

Effective therapy is available for most tick-borne diseases.[2,8] The emergence of Lyme disease and ehrlichiosis has led to a heightened public and physician awareness of the importance of tick-borne diseases.[1,2] In recent years, there has been an increased reporting of tick bites by patients and a real increase in the diagnosis of tick-borne illnesses. Serologic testing appears to be useful in appropriate clinical settings, and it has become widely available so that physicians can confirm infection by the more common tick-borne pathogens.[1]

This article reviews the pulmonary manifestations of four major tick-borne diseases: Lyme disease, ehrlichiosis, tularemia, and Rocky Mountain spotted

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Table 1—*Tick-borne Diseases and Their Clinical Features*

Disease, Organism	Vector	Clinical Features	Pulmonary Complication	Chest Radiograph
Lyme disease *B burgdorferi*	Black-legged tick, sheep tick	Erythema migrans, heart block, facial palsy	Cough, ARDS, respiratory failure	Pulmonary edema, cardiomegaly
RMSF *R rickettsii*	American dog tick	Fever, spotted rash, headache, myalgia, abdominal pain	Pharyngitis, pleural effusion, pleurisy	Pleural effusion, diffuse infiltrates, pulmonary edema
Ehrlichiosis *E chaffeensis*	American dog tick, Lone Star tick	Fever, headache, maculopapular rash, encephalopathy	Respiratory failure, ARDS, pharyngitis	Pulmonary infiltrates, pulmonary edema
Tularemia *F tularensis*	American dog tick, Lone Star tick, Rocky Mountain wood tick	Fever, headache, malaise	Pneumonia, cough, pleural effusion	Pleural effusion, patchy infiltrates
Babesiosis *B microti*	Black-legged tick, sheep tick	Fever, headache, myalgia	Cough, ARDS	Pulmonary edema
Tick paralysis Neurotoxin	Black-legged tick, American dog tick, Lone Star tick, Rocky Mountain wood tick	Weakness, examine for tick	Respiratory failure	Bilateral raised hemidiaphragms

fever (RMSF). The clinical features and treatment options for tick-borne diseases are outlined in order to improve the diagnostic evaluation and clinical management of patients presenting with respiratory complaints and a history of a tick bite.

Lyme Disease

Clinical Features and Epidemiology

Lyme disease is the most commonly reported vector-borne disease in the United States and Europe.[1,2,9] Its cause is *Borrelia burgdorferi*, a spirochete that is transmitted to man through the bite of the black-legged tick.[15,16] *B burgdorferi* can infect rodents, deer, and several species of human-biting ticks, including the western black-legged tick (Fig 1), the American dog tick, and the Lone Star tick.[17] Because the small mammals that carry the ticks that transmit *B burgdorferi* are commonly found in wooded areas or parks, patients often provide a history of outdoor activities.[12] In the United States, $>$ 50,000 cases of Lyme disease were reported between 1982 and 1992 in 48 states.[18] Most cases in the United States have occurred in the northeastern coastal states and in the upper Midwest where the vector is the black-legged tick, and in northern California where the vector is the western black-legged tick. In the parts of Europe where the vector is the sheep tick, the annual incidence of Lyme disease approximates 70/100,000 of the population.[9,19] In the Netherlands, the incidence of erythema migrans is approximately 40/100,000 of the population.[20] Human infections occur during the months of May through August when outdoor activities and tick nymphal stages are at their peak.[21] Transmission of the spirochete requires a minimum of 36 to 48 h of attachment.[22] Tick nymphs are small and hard to detect, and they may remain attached for long periods of time. Nymphs, therefore, are thought to be the most important vectors of Lyme disease (Fig 1). It has been estimated that approximately 1.4% of tick bites lead to clinical features of Lyme

Table 2—*Tick Vectors of Human Disease and Their Geographic Distributions*

Family	Genus	Species	Common Name	Distribution
Hard ticks (Ixodidae)	Ioxodes	*Ixodes ricinus*	Sheep tick	Europe
		Ixodes scapularis	Black-legged tick	Northeastern and eastern United States
		Ixodes pacificus	Western black-legged tick	Western United States
		Ixodes holocyclus	Australian paralysis tick	Australia
	Dermacentor	*Dermacentor variabilis*	American dog tick	Southern and eastern United States
		Dermacentor andersoni	Rocky Mountain wood tick	Southern and western United States
	Amblyomma	*Amblyomma americanum*	The Lone Star tick	Southern and eastern United States
	Rhipicephalus	*Rhipicephalus sanguineus*	Brown dog tick	United States, Australia, Europe
Soft ticks (Argasidae)	Ornithodoros	*Ornithodoros moubata*	African hut tampan	eastern and southern Africa
		Ornithodoros coriaceus	Pajaroello tick	southern United States and Mexico

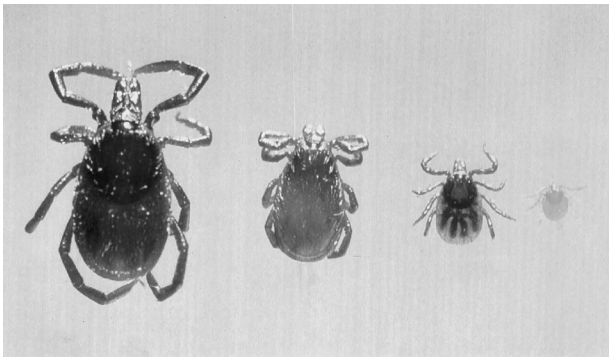

FIGURE 1. Left to right: Adult female, adult male, nymph and larval forms of *Ixodes pacificus* (Western black-legged tick). The adult female measures 10 mm in length. This photograph is courtesy of The Scientific Photographic Laboratory, University of California at Berkeley, Berkeley, CA.

FIGURE 2. Adult female *Dermacentor andersoni* (Rocky Mountain wood tick). The adult female measures 12 mm in length. This photograph is courtesy of the Rocky Mountain Laboratory, National Institute of Allergy and Infectious Diseases, National Institutes of Health, Hamilton, MT.

disease in endemic areas.[19,20] More than 1,000 people acquire the infection in the United States each year.[1,18]

In 75% of the cases of Lyme disease, there is no history of a tick bite.[3,9,21,22] However, within 1 week of infection by *B burgdorferi*, a characteristic macular skin rash, erythema migrans, develops at the site of the tick bite in 80% of the cases (stage 1 Lyme disease).[23] This rash may be accompanied by fever, headache, fatigue, arthralgia, and myalgia. Although respiratory symptoms are unusual, cough has been reported.[24] Erythema migrans resolves spontaneously within 4 weeks, but untreated infection with *B burgdorferi* can lead to disseminated disease, with widespread skin lesions and progressive neurologic involvement in at least a small proportion of the cases (stage 2 Lyme disease).[25] The most frequent neurologic manifestation of early or disseminated Lyme disease is cranial neuritis. Facial palsy is particularly common, and it is reported in approximately 3% of the cases (Fig 3). Many other neurologic sequelae of Lyme disease have been described, including aseptic meningitis, transverse myelitis, and mononeuritis multiplex.[25,26] Only a small proportion of the cases demonstrates neurologic disease, and the overall prognosis of stage 2 Lyme disease appears to be excellent.[27] Pharyngitis has been reported in 17% of the patients with stage 2 Lyme disease.[24] One fatal case of ARDS has been reported.[7] Neuroborreliosis has been implicated as a cause of respiratory failure.[28] Three cases of Lyme disease associated with encephalopathy and nocturnal hypoventilation or prolonged central apnea have been reported. In these cases, tracheotomy and prolonged ventilatory support were required because of abnormal central respiratory disturbances.[28]

In stage 2 Lyme disease, patients may complain of shortness of breath due to cardiac involvement or phrenic nerve palsy. We have recently described a case in which diaphragmatic paralysis due to Lyme disease was successfully treated with tetracycline antibiotics.[29] Cardiac complications of Lyme disease, which are reported in 8% of North American patients, occur in the early disseminated phase of the disease, and they consist of varying degrees of atrioventricular (AV) block, pancarditis, and congestive cardiac failure.[30–32] Patients with first-degree heart block are generally asymptomatic. Symptoms of dyspnea and palpitations are seen in patients with high-degree AV block and heart failure. Complete heart block rarely lasts longer than 1 week. Patients with high-degree AV block or a PR interval $>$ 300 ms should be hospitalized for telemetry because they have an increased risk of developing asystole.[31,33] Unlike the other features of Lyme disease, early antibiotic therapy does not decrease the duration of cardiac involvement.[32] Prednisone (60 mg/d) or salicylates (3.6 g/d) are recommended for the treatment of patients with high-degree AV block, a PR interval $>$ 300 ms, or cardiomegaly. In patients with severe or symptomatic heart block, temporary pacing may be necessary.[33,34]

In addition to cardiac conduction disturbance, *B burgdorferi* can cause inflammation of all cardiac layers. Features of myocarditis, cardiomyopathy, or pericarditis are commonly described in patients with Lyme carditis.[35] Histopathology of the heart reveals a discrepancy between the small number of spirochetes recovered and the extent of the lymphocytic infiltrate, which suggests a combined

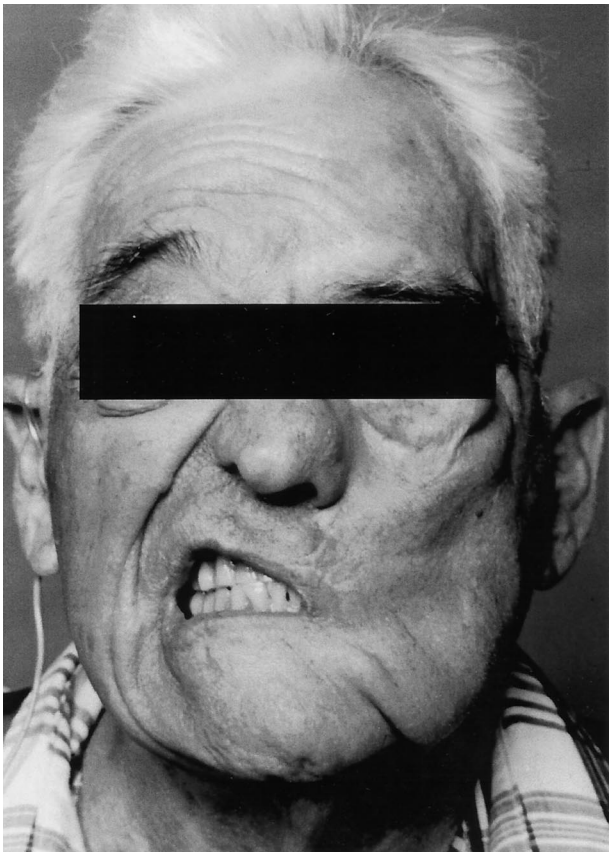

FIGURE 3. Facial palsy. This photograph is courtesy of the Department of Medicine, Stanford University Medical Center, Palo Alto, CA.

cardiac effect of local spirochetal infection and an abnormal immune reaction to the infection.[36,37] This immune reaction is the target of anti-inflammatory and steroid therapy. Lyme disease may even cause chronic congestive cardiomyopathy, with resultant shortness of breath and exercise intolerance. The prevalence of serum antibodies to *B burgdorferi* has been found to be higher in patients with dilated cardiomyopathy than in the control groups in one study.[37] Moreover, *B burgdorferi* has been isolated from an endomyocardial biopsy specimen of a patient with long-standing cardiomyopathy.[38] Potential mortality in Lyme disease is thought to be related to cardiac involvement and ARDS.[7,32,35,38,39] No respiratory complications have been reported in patients with stage 3 Lyme disease (*ie*, chronic arthritis, dermatitis, CNS involvement).

Diagnosis and Treatment

For a patient with symptoms of dyspnea and a history of erythema migrans, neurologic dysfunction, or recent tick bites, a differential diagnosis of Lyme disease should be considered. IgM antibodies directed against *B burgdorferi* usually appear 3 to 6 weeks after infection. Serology (enzyme-linked immunosorbent assay) is nearly always positive, but a negative test result does not exclude Lyme disease as a cause.[40] Western blotting is useful for clarifying low-titer positive results.[40] A human vaccine against *B burgdorferi* [41,42] has recently been approved by the US Food and Drug Administration. Lyme disease can be prevented by avoiding tick exposure[43] and by using antibiotic therapy early in the disease.[42,44] Systemic antibiotic therapy is probably not beneficial for the treatment of tick bites in the absence of a clinical disease.[45]

Lyme disease is an important cause of neurologic morbidity because it is preventable and reversible with appropriate antibiotic therapy. Oral tetracycline antibiotics are the treatments of choice for all stages of Lyme disease.[45] In a controlled study of disseminated Lyme disease, IV ceftriaxone (2 g daily for 2 weeks) and oral doxycycline (100 mg twice daily for 3 weeks) showed similar clinical cure rates at 9 months (85% and 88%, respectively).[44] IV ceftriaxone is currently recommended for patients with meningitis or encephalopathy because of its better penetration into cerebrospinal fluid.[42] However, for most patients with Lyme disease, IV therapy appears to be no more effective than oral therapy.[45]

RMSF

Clinical Features and Epidemiology

RMSF is the most frequently reported rickettsial disease in the United States. Its cause is *Rickettsia rickettsii*, a small pleomorphic obligate intracellular parasite that survives only briefly outside a host.[46] In the United States, *R rickettsii* is transmitted by the American dog tick in the eastern states and the Rocky Mountain wood tick (Fig 2) in the western states. RMSF is widely distributed across the United States. Most infections are acquired in the south Atlantic coastal, western, and south central states.[1] Approximately 1,000 cases are reported annually. Almost all cases are reported during the months of April through September. Most infections occur in rural or suburban settings, but rare urban outbreaks have occurred.[47] Children are at particular risk. Other risk factors include exposure to dogs and residence in a wooded area.[48] Tick-borne spotted fevers, including Mediterranean spotted fever (*Rickettsia conorii*), North Asian tick typhus (*Rickettsia sibirica*), Queensland tick typhus (*Rickettsia australis*), and Oriental spotted fever (*Rickettsia japonica*) have a worldwide distribution, and they may lead to respiratory failure and death.[49,50]

Table 3—*Tick-borne Diseases: Diagnosis and Management

Disease, Organism	Incubation Period	Specific Testing	Therapy (Daily Dose and Duration)
Lyme disease *B burgdorferi*	Stage 1: 1 wk Stage 2: 5–6 wk	IgM, IgG, ELISA (Western blot)	Doxycycline 200 mg for 21 d or ceftriaxone 2 g for 14 d
Rocky Mountain spotted fever R rickettsii	2 wk	IgM, IgG, serology	Doxycycline 200 mg for 10 d or chloramphenicol 2.4 g for 10 d (until afebrile for 2–3 d)
Ehrlichiosis *E chaffeensis*	< 3 wk	Immunofluoresence, antibody assay	Doxycycline 200 mg for 14 d
Tularemia *F tularensis*	3–5 d	Agglutinating antibody	Gentamicin 3–5 mg/kg for 14 d
Babesiosis *B microti* *B equi*	1 wk	Geimsa stain of blood smear, indirect immunofluoresence antibody testing	Quinine 2.6 g for 7–10 d and clindamycin 2.4 g for 7–10 d
Tick paralysis Neurotoxin	1–3 d tick may be attached	Examine for tick	Tick removal

*ELISA = enzyme-linked immunosorbent assay.

A classic triad of fever, rash, and tick bite is present in the majority of confirmed cases. Within 2 weeks of the tick bite, fever is reported in virtually all cases with associated malaise (95%), frontal headache (90%), myalgia (80%), and vomiting (60%). Tick bites are reported in one half of the cases.

The pulmonary manifestations of RMSF include cough (33%), pharyngitis (8%), and pleuritic chest pain (17%).[51] Between 10% and 36% of the patients have a pleural effusion on the chest radiograph. Abdominal pain, hepatosplenomegaly, meningism, and myocarditis may also develop. In 90% of the cases, a rash typically occurs 1 to 14 days after the onset of illness. It initially appears as macules on the wrists and ankles, and subsequently spreads to involve the trunk, face, palms, and soles. These lesions often develop papular or purpuric features (vasculitis). The vasculitis is thought to be responsible for pulmonary infiltrates that are seen on chest radiographs in one third of the cases (85% have an interstitial pattern; 15% have a pattern of consolidation). ARDS is reported to develop in 7% of the patients, and an additional 30% of the patients have cardiogenic pulmonary edema (vasculitis is thought to adversely affect the myocardial pump function).[52]

Diagnosis and Treatment

The diagnosis is made on the basis of the above clinical features. Leukopenia, thrombocytopenia, elevated serum hepatic transaminase values, and hyponatremia are commonly noted. The definitive diagnostic test is direct immunofluorescent examination of skin biopsy samples for *R rickettsii* or *R conorii*.[50,53] Antibodies to *R rickettsii* are detectable 7 to 10 days after the onset of illness, and they fall to nondiagnostic titers within 2 months. Early treatment may blunt or delay the increase in antibody levels.[54] The Weil-Felix reaction lacks sensitivity and specificity, and it is not currently recommended.[55] Culture and polymerase chain reaction techniques are used to detect *R rickettsii*, but they are not yet available for clinical diagnostic purposes.[55]

Chloramphenicol (50 mg/kg/d) or tetracycline (25 mg/kg/d) antibiotic therapy reduces the mortality rate from 25 to 5%. Antibiotic therapy is recommended for the treatment of suspected or confirmed cases of spotted fever group rickettsioses in adults.[56] Recent work suggests that levofloxacin may prove to be an effective alternative.[57] Therapy is continued until the patient is afebrile for 1 to 2 days. Large doses of corticosteroids are sometimes given to patients with severe toxemia.

Ehrlichiosis

Clinical Features and Epidemiology

Ehrlichia chaffeensis is the sole causative agent of human ehrlichiosis in the United States. The Ehrlichia species are small Gram-negative, pleomorphic coccobacilli transmitted by the bite of the American dog tick and the Lone Star tick. Ehrlichia infects the cytoplasm of circulating leukocytes causing intracellular clumps (morulae), which can be seen on light microscopy. Several hundred cases have now been described in the United States and Europe since the first description of a case in 1987.[58–60] The majority of cases are reported in May, June, or July. In endemic areas, the incidence is thought to be as high as 3 to 5/100,000 of the population.[59] In approximately 90% of the cases, patients have a history of a tick bite in the 3-week period preceding the onset of illness.[61] After a median incubation time of 7 days,

ehrlichiosis causes a syndrome dominated by fever and headache. Other symptoms include nausea, vomiting, myalgia, and anorexia. Twenty percent of the patients report a maculopapular skin rash. Severe disease is characterized by acute renal failure and encephalopathy.

Ehrlichiosis can cause pneumonia and fatal respiratory failure.[62–64] Cough is present in 39% of the cases, and sore throat and pharyngitis are reported in 22 to 33% of the cases. In 75% of children and 39% of adults with ehrlichiosis, pulmonary infiltrates are present on the chest radiograph. ARDS is reported to develop in 11 to 18% of the patients.[61]

Diagnosis and Treatment

The diagnosis is made on clinical grounds, and serology provides a retrospective confirmation. Hence, serum samples should be taken at the onset of illness as well as 4 weeks later (for acute and convalescent Ehrlichia titers).[63] Nonspecific laboratory findings include lymphopenia, thrombocytopenia, raised liver enzyme levels, and pleocytosis of the cerebrospinal fluid.[63,65] Tetracycline (or chloramphenicol) antibiotic therapy for 14 days is currently the treatment of choice.[61,63]

Tularemia

Clinical Features and Epidemiology

The causative agent of tularemia was discovered in 1912 in Tulare County, California.[66] *Francisella tularensis* is a small, Gram-negative, nonmotile coccobacillus, which is found in rabbits, hares, rodents, and ticks. Transmission to humans may occur by direct contact, inhalation, ingestion, or tick bite by the Lone Star tick, the Rocky Mountain wood tick, or the American dog tick. Approximately 200 to 300 cases are reported each year in the United States (predominantly in Arkansas, Missouri, and Oklahoma). Cases have been also been reported in Sweden and eastern Europe.[67,68] Most cases occur in the summertime.[69]

The clinical features of disease depend on the route of inoculation. Ulceroglandular (*ie*, an ulcer at the site of the bite associated with painful regional lymphadenopathy), glandular (lymphadenopathy), typhoidal (fever, chills, headache, abdominal pain), primary oropharyngeal, and primary pneumonic forms have been recognized to occur in tularemia. Tularemia is a severe illness (1 to 3% mortality) characterized by the sudden onset of fever, headache, malaise, and fatigue after a 3- to 5-day incubation period.[70] Reported pulmonary features include cough (23 to 40%) and pharyngitis (15 to 50%).[71] Pleural effusion occurs in 20 to 30% of patients with early disease and in as much as 55% of patients in later stages.[72] Secondary pneumonia and pharyngitis are common complications of tick-borne tularemia. Pneumonia, which occurs in approximately 25% of the cases, is associated with increased morbidity and mortality.[73] Laboratory testing is usually unremarkable, although serum hepatic transaminase levels are commonly elevated. Parenchymal infiltrates (74%) are typically patchy, ill-defined, and multilobar. A minority of patients have a radiographic triad of oval opacities, hilar lymphadenopathy, and pleural effusion.[74,75] Tularemia has been reported to progress to ARDS in 12% of the patients.[72]

Diagnosis and Treatment

The diagnosis is made on clinical grounds, but it can be confirmed by a fourfold rise in agglutinating antibodies to *F tularensis* between acute and convalescing sera.[73] Either streptomycin or gentamicin therapy for 10 to 14 days appears to be equally effective.[76,77] A considerable clinical improvement is reported to occur within 48 h of the appropriate therapy. Immunity after infection is only partial, and cases of reinfection have been reported.[78] A live attenuated tularemia vaccine is available for laboratory workers, but it is not useful for the prevention of tick-borne tularemia.

Other Tick-Borne Diseases

Colorado tick fever is an acute viral illness caused by a double-stranded RNA virus (genus, Orbivirus), which is transmitted by the Rocky Mountain wood tick. A single case of atypical pneumonia has been described.[79] Treatment is supportive, and most patients recover after a mild illness.[3] Relapsing fever is caused by various tick-borne spirochete organisms causing malaise and nonproductive cough in about one tenth of the cases. One case of ARDS that was due to relapsing fever has been reported.[80]

Babesiosis is the only known tick-borne protozoal infection in the United States. *Babesia microti* is transmitted by the black-legged tick in the northeastern states. *Babesia equi* is transmitted by the western black-legged tick in California.[2] Symptoms include malaise, fatigue, and anorexia beginning 1 week after inoculation. Fever, sweats, myalgia, and headache develop several days later. Respiratory symptoms of cough (14%) and pharyngitis (7%) occur in a minority of cases. Several cases of ARDS have been ascribed to babesiosis. All occurred after the institution of antimicrobial therapy.[81–83] Approximately 20% of the cases of babesiosis have clinical and serologic evidence of concurrent Lyme disease.[84] The diagnosis of babesiosis is confirmed by finding

intraerythrocytic rings in Giemsa-stained peripheral blood smears or by serologic testing. The current recommended therapy consists of oral quinine plus clindamycin.[85,86]

The salivary glands of engorged, gravid female ticks produce a neurotoxin that inhibits motor-stimulus conduction.[87] This neurotoxin is believed to be the cause of tick paralysis. Several ticks are known to cause paralysis in North America: the Rocky Mountain wood tick, the Lone Star tick, the black-legged tick, and the American dog tick. Most cases have been reported during the spring and summer. Tick paralysis characteristically leads to symmetric weakness of the lower extremities, progressing to an ascending flaccid paralysis over several hours or days. There is an absence of sensory symptoms. Tick paralysis may present as acute ataxia without muscle weakness.[88] The symptoms resolve within several days of removing the tick. An antitoxin is available for serious cases of tick paralysis.[89] Untreated, the paralysis can lead to fatal respiratory failure with reported mortality rates of 10 to 12%.[89,90]

Discussion

In the context of a patient with respiratory symptoms and a recent history of tick bites, it is useful to be aware of the clinical features, epidemiology, and treatments of tick-borne pulmonary diseases. This review describes the important pathogens that ticks can transmit to humans. When the ecologic niches that harbor infectious agents in enzootic tick-mammalian cycles come in close proximity to human habitats, there is an increased transmission of disease.[91] Renewed public interest in recreational outdoor pursuits and activities has resulted in a greater number of people at risk for infection by tick-borne parasites. In addition to the increased reporting of tick bites by patients, there appears to be a real increased incidence of these diseases.[92] Indeed, tick-borne disease has now become endemic in some areas of the United States. Although a Lyme vaccine has recently been approved by the US Food and Drug Administration, effective vaccination is not currently available for most other tick-borne diseases.[41,42] Disease prevention therefore depends on the use of tick-repellant ointments, long-sleeved clothing, and the avoidance of activities in endemic areas.[43] The early use of antibiotics is not currently recommended for tick bites in the absence of a tick-borne disease.[92] Antibiotic therapy does halt the progression of most tick-borne illnesses, and thus may be indicated in patients who have pulmonary complications.

This review describes the diverse pulmonary complications of tick-borne diseases. The clinical features of these disorders are often subtle; therefore, a high clinical index of suspicion is required to make an accurate diagnosis. An attempt should be made at a specific diagnosis even after empiric therapy has been started because the various pathogens transmitted by ticks demand different treatments. Initial therapy (Table 3) should be given for the most likely differential diagnosis based on the patient's clinical features and geographic epidemiology. The clinical features of tick-borne diseases may overlap in some patients because it is possible that patients may be coinfected with two or more tick-borne pathogens.[93] Not only can ticks be coinfected with the Babesia, Ehrlichia, and Borrelia species, but subjects at high risk for tick bites may be inoculated with different organisms by way of multiple tick bites.[94,95] Serology is helpful in confirming a diagnosis. Routine serologic screening is probably inappropriate in the absence of strong clinical indicators of disease.[92] For patients who have respiratory complaints and histories of tick bites, it is important to consider a diagnosis of tick-borne pulmonary disease because effective antibiotic therapy may lead to greatly improved outcomes.

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