Seroepidemiology of Emerging Tickborne Infectious Diseases in a Northern California Community

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A seroprevalence and risk factor study of emerging tickborne infectious diseases (Lyme disease, ehrlichiosis, and babesiosis) was conducted among 230 residents of a semirural community in Sonoma County, California. Over 50% of residents reported finding a tick on themselves in the preceding 12 months. Samples from 51 (23%) residents were seroreactive to antigens from one or more tickborne disease agents: 1.4% to Borrelia burgdorferi, 0.4% to Ehrlichia chaffeensis, and 17.8% to the Babesia-like piroplasm WA1. Only 14 (27%) of these seroreactive residents reported one or more symptoms compatible with these diseases. Seroreactivity was significantly associated with younger age (<16 years), longer residence in the community (11–20 years), and having had a physician’s diagnosis of Lyme disease. In northern California, the risk of infection with these emerging tickborne diseases, particularly in children, may be greater than previously recognized.

In the last decade, tickborne infectious diseases in humans have been the focus of increased interest and concern [1, 2]. While cases of established tickborne infectious diseases (Rocky Mountain spotted fever, Colorado tick fever, tularemia, and relapsing fever) continue to occur in the United States, several newly recognized tickborne diseases (Lyme disease, babesiosis, and two forms of ehrlichiosis) have been described since 1975. Lyme disease is caused by infection with the spirochete Borrelia burgdorferi. It is transmitted to persons in North America through the bite of Ixodes scapularis and Ixodes pacificus ticks and is currently the most frequently reported vectorborne disease in the United States [3]. Babesiosis is a malaria-like infection of erythrocytes caused by the protozoan parasite Babesia microti. It is transmitted by I. scapularis and is most frequently reported in the northeastern United States [4, 5]. Recently, a novel Babesia-like piroplasm, designated WA1, has been identified as an infectious agent of humans in the western United States [6–8]. The first case of human monocytic ehrlichiosis (HME), caused by infection with the rickettsia Ehrlichia chaffeensis and apparently transmitted by Amblyomma americanum ticks, occurred in an Arkansas patient in 1986 [9–12]. Human granulocytic ehrlichiosis (HGE), caused by an organism closely related or identical to Ehrlichia chaffeensis and most likely transmitted by one or more Ixodes species, has been more recently described [13–15].

Northern coastal California, with the northeastern and upper Midwest states, is one of three principal regions in the United States that is Lyme disease–endemic [16]. Humboldt, Lake, Mendocino, and Sonoma counties accounted for 40% of 716 Lyme disease cases reported in California during 1991–1994 (CDC, unpublished data). A recent active surveillance study in these counties estimated the annual incidence of early Lyme disease at 5.5 cases/100,000 population [17]. However, the true risk of B. burgdorferi infection in this region is unknown and may be higher since some infected persons do not consult a physician for their illness, may be misdiagnosed, or may otherwise not be identified by the surveillance system. Residents of Lyme disease–endemic areas may be at increased risk of other tickborne diseases [18], and while isolated cases of human ehrlichiosis and babesiosis have been reported in California [8, 15], the epidemiology of these diseases in the state is poorly understood.

This report summarizes results of a study to estimate the seroprevalence of and factors associated with exposure to B. burgdorferi, ehrlichiae, and babesiae in residents of a community in Sonoma County in northern California.
Methods

Study area. The investigation was conducted in a semirural residential subdivision (community A) of Sonoma County. The area encompasses 153 hectares (378 acres) on the eastern slope of the foothills in the Sonoma Valley. Woodlands of California oak and California bay trees with dense subarboreal leaf litter are typical of the undeveloped area. The climate is Mediterranean, with cool, moist winters and hot, dry summers. Black-tailed deer (Odocoileus hemionus), rodents, reptiles, birds, and other wildlife exist throughout the community. The abundant wildlife and dense, moist ground cover support large focal populations of I. pacificus and, to a lesser extent, Dermacentor occidentalis ticks.

Study population. Approximately 450 persons are full-time residents of community A. Residents occupy 180 single-family dwellings on lots ranging in size from 0.81 to 20.24 hectares (2–50 acres). A letter that described the study and invited residents to attend one of six local meetings was mailed to every household 1 week prior to the investigation in August 1994. Persons who were not residents of community A at the time of the study were excluded from participation. Residents who did not attend one of the six meetings were telephoned and encouraged to attend a final seventh meeting.

Questionnaire. At each meeting, study participants were asked to complete a self-administered questionnaire; parents completed separate questionnaires for themselves and for each of their children. Information was obtained about demographic factors (e.g., age, sex, ethnicity), duration of residence in community A, size and character of residential property, pet ownership, recreational activities and travel, and preventive measures used against tick bites. Participants were also asked to indicate if they believed they had ever had Lyme disease, whether they had been diagnosed with and treated by a physician for Lyme disease, and what symptoms they associated with their illness.

Seroepidemiology. A 10-mL sample of venous blood was obtained from community A study participants following completion of the questionnaire and informed consent. A second series of serum samples to be used as a comparison group was collected from residents of counties in northern California with low reported incidences of Lyme disease. These serum samples were obtained from units of blood donated to a collection facility in Sacramento County over a 2-day period in February 1995.

All samples were tested for antibodies to B. burgdorferi by methods described previously [19, 20], with minor modifications. Briefly, samples were tested by combined IgG and IgM EIA using as antigen a flagellar preparation from high-passaged prototype B. burgdorferi sensu stricto strain B31, isolated from I. scapularis collected in New York [21]. All samples demonstrating equivocal or positive range reactivity in EIA underwent subsequent confirmatory testing by IgG Western immunoblotting using as antigen two different sources of low-passaged B. burgdorferi B31 and a California isolate, CA92-0953 (MarDx Diagnostics, Carlsbad, CA). The California strain was isolated in 1992 from an erythema migrans lesion of a patient exposed in Mendocino County, California (unpublished data). The B31 and California strains express a full complement of proteins for testing and analysis of Western immunoblot reactivity as determined by the use of a panel of nine anti–B. burgdorferi monoclonal antibodies [19, 20] and reference serum samples. Manufacturer’s instructions were followed in the use of both immunoblots. Samples with at least 5 of 10 diagnostic bands present on immunoblotting were considered reactive [22].

An IFA test was used to detect antibodies to E. chaffeensis and E. equi. The E. chaffeensis antigen (provided by CDC) has been described [11, 23]. All samples were screened by IFA for E. equi (MRK strain) using E. equi organisms propagated in equine neutrophils and provided by J. Madigan (University of California, Davis). Because of the possibility of nonspecific neutrophil reactions with some sera, reactive samples were confirmed with commercial E. equi slides (Linmed Biologics, Brea, CA) that use MRK antigen grown in KG-1 (ATCC CCL 246), a human cell line derived from bone marrow from a human patient with acute myelogenous leukemia. Starting at 1:64, serial 2-fold dilutions of sera were made in 0.01 M PBS, pH 7.3; controls were included in each run. After 20 min of incubation at 36°C, the slides were washed in PBS for 5 min, and a 1:250 dilution of fluorescein-conjugated goat anti–human IgG (Organon Teknika, Westchester, PA) was added. The slides were incubated for 20 min, washed in PBS for 5 min, mounted with coverslips in 90% glycerol in TRIS buffer, pH 8.5, and read in a fluorescence microscope. Serologic results were reported as the reciprocal of the highest dilution at which specific fluorescence was observed. Titters of ≥64 were considered reactive.

Samples were tested for antibodies against intraerythrocytic stages of Babesia-like piroplasm WA1 and B. microti isolates by IFA. The WA1 antigen was originally obtained from a naturally infected patient from eastern Washington State [7]; the B. microti antigen was from a naturally infected patient from Minnesota [24]. Both isolates were maintained by serial passage in female golden hamsters. Antigen slides were prepared as previously described [25] and fixed in acetone. Before use, slides were removed from the freezer and thawed at 37°C for 10 min. Serial 2-fold dilution of sera in Dulbeco’s PBS (DPBS, pH 7.2; GIBCO Laboratories, Grand Island, NY) were made, starting at 1:80 and ending at 1:5120. Diluted sera (10 μL) were placed in separate wells on the slide. Slides were incubated at 37°C for 25 min in a moist chamber, washed for 5 min in DPBS, and dried with cool air. Ten microliters of fluorescein-conjugated polyclonal goat anti–human IgG (H+L) (Kirkegaard & Perry Laboratories, Gaithersburg, MD) was added to each well. After a 25-min incubation and a 5-min wash, an overlay of 25% (wt/vol) glycerin/PBS and a coverslip were placed on each slide. Positive and negative controls were run with each series. Slides were read independently by 2 observers using a fluorescence microscope (Zeiss, Oberkochen, Germany). Results were reported as the reciprocal of the highest dilution at which specific fluorescence was observed. Titters of ≥320 were considered reactive.

Statistical analysis. Differences between groups were determined by the Pearson χ² test of independence or Fisher’s exact test (two-tailed) for nominal variables and by Kruskal-Wallis analysis of variance by ranks for continuous variables. Factors associated with the number of recognized tick encounters were assessed using multiple linear regression. Factors associated with seroreactivity were evaluated using fixed-effects multiple logistic regression. Household clustering of seroreactive persons was assessed by fitting a logistic-binomial regression model. Associated probabilities of P < .05 were considered statistically significant.

Results

Study population. Questionnaires were completed by 230 community A residents (51% of the estimated 450 total popula-
Table 1. Characteristics of community A residents who reported finding ≥1 tick on themselves in the preceding 12 months.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>≥1 tick</th>
<th>No ticks</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>117</td>
<td>108</td>
<td></td>
</tr>
<tr>
<td>Age &lt;16 years (%)</td>
<td>20 (17)</td>
<td>6 (6)</td>
<td>&lt;.01*</td>
</tr>
<tr>
<td>Property &gt;6.07 hectares (15 acres) (%)</td>
<td>15 (13)</td>
<td>2 (2)</td>
<td>&lt;.01*</td>
</tr>
<tr>
<td>Own ≥1 dogs (%)</td>
<td>82 (71)</td>
<td>56 (53)</td>
<td>&lt;.01*</td>
</tr>
<tr>
<td>Own ≥1 horses (%)</td>
<td>33 (29)</td>
<td>11 (10)</td>
<td>&lt;.01*</td>
</tr>
<tr>
<td>Deer-excluding fence around property (%)</td>
<td>19 (16)</td>
<td>33 (31)</td>
<td>.01*</td>
</tr>
<tr>
<td>Median time (h/week) engaged in outdoor recreation (range)</td>
<td>5 (0–50)</td>
<td>2 (0–20)</td>
<td>&lt;.01¹</td>
</tr>
<tr>
<td>Median time (h/week) spent hiking on trails in wooded areas (range)</td>
<td>1 (0–30)</td>
<td>0 (0–9)</td>
<td>&lt;.01¹</td>
</tr>
<tr>
<td>Median time (h/week) spent hiking off trails in wooded areas (range)</td>
<td>1 (0–20)</td>
<td>0 (0–18)</td>
<td>&lt;.01¹</td>
</tr>
</tbody>
</table>

* χ² test of independence.
¹ Kruskal-Wallis analysis of variance.

Table 2. Prevalence of seroreactivity to 5 tickborne pathogens in residents of 2 northern California communities, 1994.

<table>
<thead>
<tr>
<th>Antigen</th>
<th>Strain</th>
<th>Community A residents, Sonoma County (n = 219)</th>
<th>Comparison group, Sacramento blood bank (n = 124)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. reactive (%)</td>
<td>IFA titer (no.)</td>
<td>No. reactive (%)</td>
</tr>
<tr>
<td><em>Borrelia burgdorferi</em></td>
<td>B31*</td>
<td>3 (1.4)</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>10 (4.6)</td>
<td>64 (5)</td>
<td></td>
</tr>
<tr>
<td><em>Ehrlichia chaffeensis</em></td>
<td>128 (3)</td>
<td>256 (2)</td>
<td></td>
</tr>
<tr>
<td><em>Ehrlichia equi</em></td>
<td>1 (0.4)</td>
<td>512 (1)</td>
<td></td>
</tr>
<tr>
<td><em>Babesia species</em></td>
<td>WA1</td>
<td>39 (17.8)</td>
<td>320 (20)</td>
</tr>
<tr>
<td></td>
<td>640 (9)</td>
<td>1280 (8)</td>
<td>640 (5)</td>
</tr>
<tr>
<td></td>
<td>2560 (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Babesia microti</em></td>
<td>0</td>
<td>51 (23.3)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>51 (23.3)</td>
<td>25 (20.1)</td>
<td></td>
</tr>
</tbody>
</table>

NOTE. NA, not applicable.

* All community A serum samples were also tested using CA92-0953 strain *B. burgdorferi* antigen; results were identical to those using B31 strain.

¹ One sample was reactive to both *B. burgdorferi* and *E. equi*; 1 was reactive to both *E. chaffeensis* and *Babesia* species WA1.
B. burgdorferi between the B31 and CA92-0953 strains used for immunoblotting. None of 124 sera from the comparison group was reactive to B. burgdorferi, E. chaffeensis, E. equi, or B. microti; 25 (20.1%) were reactive to WA1.

Community A residents who were seroreactive to at least one agent were more likely to have had a physician’s diagnosis of Lyme disease than were residents who were seronegative (25% vs. 6.7%; P < .01; table 3). Of the 24 residents who reported having a physician’s diagnosis of Lyme disease, 13 (54%) were seroreactive to $\geq$1 agents (3 to B. burgdorferi, 3 to E. chaffeensis, and 7 to WA1) compared with 38 (20%) of 190 residents who were not so diagnosed (P < .01). All 3 (100%) B. burgdorferi—reactive, 3 (30%) of 10 E. chaffeensis—reactive, and 8 (21%) of 39 WA1-reactive persons reported at least one symptom; 35 (69%) seroreactive persons reported no symptoms. The 8 WA1-reactive persons who reported symptoms had significantly higher titers than did the 31 asymptomatic WA1-reactive persons (P = .03).

Nine (50%) of 18 persons <16 years old were seroreactive compared with 41 (21%) of 197 persons $\geq$16 years old (table 4). Persons who were residents of community A for 11–20 years were significantly more likely to be seroreactive than residents of $\leq$10 years (odds ratio 4.4, adjusted for age; 95% confidence interval, 2.0–9.6). Eight (10%) of 79 multiperson households had $\geq$1 seroreactive member, but statistical evidence (based on the logistic-binomial regression model) was insufficient to indicate that seroreactivity clustered within households.

Because of the association between seroreactivity and young age, separate analyses were conducted for children (<16 years old). Seroreactive children were significantly older and more likely to spend time in wooded areas, both around the home and on vacation, than were seronegative children (table 5). No other factors were significantly associated with seroreactivity in children.

### Table 3. Characteristics of community A residents seroreactive to $\geq$1 of 5 tickborne pathogens.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Seroreactive</th>
<th>Seronegative</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>51</td>
<td>168</td>
<td></td>
</tr>
<tr>
<td>Age &lt;16 years (%)</td>
<td>9 (18)</td>
<td>9 (5.3)</td>
<td>.02*</td>
</tr>
<tr>
<td>Median duration (years) of residence</td>
<td>16 (1–29)</td>
<td>9 (&lt;1–30)</td>
<td>.03*</td>
</tr>
<tr>
<td>Female (%)</td>
<td>27 (53)</td>
<td>89 (53)</td>
<td>1.0</td>
</tr>
<tr>
<td>Report Lyme disease currently</td>
<td>13 (25)</td>
<td>16 (9.5)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>or previously (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Report physician’s diagnosis of Lyme disease (%)</td>
<td>13 (25)</td>
<td>11 (6.7)</td>
<td>&lt;.01</td>
</tr>
</tbody>
</table>

NOTE. Age information was missing for 1 seroreactive and 3 seronegative residents.
- Fisher’s exact test.
- Kruskal-Wallis analysis of variance.
- $\chi^2$ test of independence.

### Table 4. Results of fixed-effects multiple logistic regression on the association of demographic, residential, and behavioral factors with seroreactivity to $\geq$1 of 5 tickborne pathogens in 219 residents of community A.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Nominal group</th>
<th>Odds ratio</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\geq$16</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;16</td>
<td>5.0</td>
<td>1.7, 14.9</td>
<td></td>
</tr>
<tr>
<td>Years of residence in community A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\leq$10</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11–20</td>
<td>4.4</td>
<td>2.0, 9.6</td>
<td></td>
</tr>
<tr>
<td>21–30</td>
<td>1.6</td>
<td>0.6, 4.4</td>
<td></td>
</tr>
</tbody>
</table>

NOTE. Results for nonsignificant (P > .05) variables are not shown.

### Discusion
The recent identification of human monocytic and granulocytic ehrlichioses and the continuing rise in reported Lyme disease cases have raised concern about these and other emerging tickborne diseases throughout the country [26–34]. This is the first serologic survey in the western United States to document exposure to several emerging tickborne pathogens in one community. While Lyme disease has previously been well documented in California, the results of this study suggest that exposure to babesiae and ehrlichiae, particularly among children, may be more common than clinically recognized and reported.

During the 3 years preceding the present study, Lyme disease incidence in Sonoma County was estimated at 10.1 and 15.8 cases/100,000 person-years by passive (CDC, unpublished data) and active [17] surveillance, respectively. During this same time, 34 (~7.5%) residents of community A claimed to have contracted Lyme disease, suggesting that the incidence of Lyme disease in community A might be higher than that in Sonoma County in general. Although <1%–2% of adult I. pacificus ticks in Sonoma County are estimated to be infected with B. burgdorferi [35, 36], populations of ticks are often focally dense, thereby increasing the potential for exposure in some regions. In the present study, 29 participants believed they had contracted Lyme disease while living in community

### Table 5. Characteristics of community A children (<16 years old) seroreactive to $\geq$1 of 5 tickborne pathogens.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Seroreactive</th>
<th>Seronegative</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>9</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Median age in years (range)</td>
<td>11 (6–15)</td>
<td>7 (2–14)</td>
<td>.05*</td>
</tr>
<tr>
<td>Play in wooded areas in community A</td>
<td>9</td>
<td>4</td>
<td>.03*</td>
</tr>
<tr>
<td>Vacation in wooded areas</td>
<td>8</td>
<td>1</td>
<td>.05*</td>
</tr>
<tr>
<td>Hunt/fish/backpack in wooded areas</td>
<td>7</td>
<td>2</td>
<td>.06*</td>
</tr>
</tbody>
</table>

* Kruskal-Wallis analysis of variance.
- Fisher’s exact test.
A, and 22 of those had received a physician’s diagnosis of Lyme disease, but only 3 had current serologic evidence of previous infection with *B. burgdorferi*. Because of its protean clinical manifestations and nonspecific symptoms, Lyme disease can be misdiagnosed as a variety of other flu-like illnesses. Conversely, in areas such as community A, where Lyme disease is endemic and awareness among physicians and the public is high, other conditions causing flu-like symptoms may be erroneously attributed to Lyme disease [37, 38].

This study identified only persons with currently detectable antibodies to *B. burgdorferi*. Some of the seronegative residents may have been previously infected with *B. burgdorferi* but failed to mount a detectable antibody response because of early treatment [39], or they may have lost detectable antibodies over time. Most persons infected with *B. burgdorferi* produce a strong IgM response within 2–3 weeks of being infected, followed in 4–6 weeks by an IgG response that can persist for >3 years [40, 41]. Ten community A residents believed they currently had Lyme disease (including the 3 who were seroreactive); for the 19 residents who claimed to have had Lyme disease in the past, the median time since onset of symptoms was 53 months (range, 3–315). While the immune response of individuals is not static, the serologic test for IgG antibodies to *B. burgdorferi* used in this study is fairly sensitive (~83% for persons tested after the first few weeks of illness [42]), and the number of false-negative results is probably small.

Recent studies indicate that substantial genetic diversity exists among *B. burgdorferi* sensu stricto isolates within the United States [43]. Although variable levels of specific gene expression have also been documented among these isolates, several common-source strains of antigen for EIA and Western immunoblot have demonstrated comparable diagnostic sensitivity and specificity [44]. In a study by Aguero-Rosenfeld et al. [45], Lyme disease patients demonstrated similar or less immunoblot reactivity with their homologous strain isolates than with B31. Likewise, in the current study, no difference in the interpretation of immunoblot reactivity was observed using either the B31 strain or the California patient strain. These results suggest that in the context of the utilized immunoblot assays, the California *B. burgdorferi* strain does not express antigens that differ significantly from those expressed by the B31 strain.

From 1987 to 1994, >300 cases of HME from 27 states were reported to the Centers for Disease Control and Prevention [46]. Most of these cases occurred in the southeastern and south-central states [47]; however, in May 1994, a case of HME was diagnosed in a California resident of Marin County, just south of Sonoma County [48]. Although the severity of *E. chaffeensis* infections can vary from asymptomatic to fatal, the ratio of clinical to subclinical infections is unknown. The estimated seroprevalence to *E. chaffeensis* of 4.6% in our study participants, most of whom recalled no specific illness, suggests that mild or subclinical illness due to infection with an *E. chaffeensis*-like agent may be more common in California than previously recognized [33].

Although HGE was originally identified in a patient from Minnesota and most cases continue to be reported from the upper Midwest [13], HGE has also been diagnosed in patients in Connecticut, Maryland, New York, Florida, and California [15, 49]. A 1990 study found elevated titers to *E. equi* in 50% of 64 healthy horses from two California ranches in the foothills of Mendocino County, just north of Sonoma County [50]. However, the serologic results of the current study suggest that in human residents of this area, HGE is less common than HME. Despite 92.8% genetic homology between *E. chaffeensis* and *E. equi* [11], there is little cross-reactivity between these 2 agents on standard serologic tests [13, 51, 52]. Therefore, it appears from our study that both HME and HGE are present in northern California, although at different prevalences.

The first recognized case of human infection with the *Babesia*-like piroplasm WA1 was in a resident of Washington State in 1991 [6]. Four cases of illness caused by infection with a WA1-like organism were reported in California in the subsequent 2 years; all patients were asplenic, and 1 Sonoma County resident died [8, 53]. Recent studies in two Northern California communities detected antibody titers >160 to WA1 in 3.5% and 16% of asymptomatic persons [8]. The seroprevalences of 18% and 20% for the Sonoma and Sacramento samples, respectively, in the present study suggest that exposure to a WA1-like agent may be more common in California than the low number of reported cases suggests. It should be noted that 8 of the participants in the Sacramento sample were residents of rural foothill communities and may have had opportunity for tick exposure comparable to that of the Sonoma participants. Considering only the 116 urban residents in the Sacramento sample and using a more conservative serologic cutoff (titer >640), 2 (1.7%) of 116 were positive for WA1 antibodies, significantly fewer than the 19 (8.7%) of 219 community A residents (*P* = .01).

As with *Ehrlichia* species, asymptomatic or subclinical infection with a WA1-like agent may be more common than previously recognized: In the current study, 80% of participants reactive to WA1 recalled no illness. The persistence of detectable antibodies to WA1 following infection is unknown. Elevated titers have been measured for up to 5 years, but it is uncertain whether these cases represent chronic subclinical infection or a persistent immune response to a resolved infection [8]. Attempts to identify active parasitemia in, and to isolate WA1-like organisms from, WA1-reactive residents of community A have been unsuccessful to date.

Infection with *ehrlichiae* or *babesiae* may account for some illnesses in community A residents that were previously attributed to or diagnosed as Lyme disease. Thirteen (54%) of the 24 community A residents who reported a physician’s diagnosis of Lyme disease were seroreactive to 1 of the 3 organisms, a proportion significantly greater than the 20% who were serore-
The tick vectors for ehrlichiae and babesiae in California are unknown. In the upper Midwest and northeastern United States, I. scapularis is the known vector of B. burgdorferi and the suspected vector of B. microti and the causative agent of HGE [13, 54, 55]. It has yet to be demonstrated whether I. pacificus, the recognized principal vector of B. burgdorferi on the Pacific Coast, serves a similar role for ehrlichiae or babesiae in this region. I. pacificus has been associated with transmission of E. equi to horses in California [56], but the suspected vector of E. chaffeensis in the Midwest, A. americanum, is not known to occur in California [57]. Dermacentor variabilis, whose density in California is much lower than that of I. pacificus and D. occidentalis, has been shown to carry E. chaffeensis and may serve as the West Coast vector for the organism [58]. Although only 2 of 39 persons in this study were reactive to >1 of the pathogens studied, this does not necessarily rule out I. pacificus as a possible common vector.

In the logistic regression analysis, young age (<16 years) and duration of residence (11–20 years) were the only factors significantly associated with being seroreactive. Length of residency was previously identified as a risk factor for seroreactivity against B. burgdorferi in a study in Mendocino County that used different serologic methods [59]. In studies of residents in Mendocino County and Massachusetts [60], seroreactivity to B. burgdorferi was associated with older age. While the cumulative incidence of seroreactivity would be expected to increase with age and duration of residence by virtue of more person-years at risk, the significantly greater proportion of children who were seroreactive in the current study indicates that the rate of infection is substantially greater for children than for adults. Although in the current study the reported number of hours spent in outdoor activities did not differ between adults and children, qualitative differences may exist in the location or type of activities that could increase a child’s risk of tick exposure. Furthermore, children may be less aware of the disease risks posed by tick bites and less conscientious about purposeful tick-bite preventive measures such as proper clothing and self-checking for ticks. Finally, since children were disproportionately underrepresented in the serologic component of this study (8/11 residents who completed questionnaires but did not provide serum samples were children), the exposure among children to these agents may be even greater than estimated here.

The true prevalence of seroreactivity in community A to these organisms is unknown, since only ~50% of residents participated in the study. Although an attempt was made to gather information from nonparticipants by telephone, it remains uncertain whether the sample obtained was representative of the community as a whole. Persons who experienced recent illness, were more informed about tickborne diseases, or believed they were at greater risk for infection may have been more likely to participate. Nonetheless, this study confirms that residents of northern coastal California are at risk of infection with several emerging tickborne pathogens. Health care providers in northern California should be aware of these organisms as potential disease agents in patients with clinically compatible illness, particularly following exposure to ticks.

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References


