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Clinician Approaches to the Diagnosis of the Patient with Suspected Lyme Disease

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Clinician Approaches to the Diagnosis of the Patient with Suspected Lyme Disease

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INTRODUCTION

Lyme disease was first described in 1977 and became a reportable disease in 1991 (Boltri et al,2002; Steere et al, 1977). Until 1995, the case definition was non-uniform (Boltri et al, 2002). Currently, the CDC guidelines define confirmed Lyme disease as "either: (a) physician-diagnosied erythema migrans ≥5 cm in diameter or (b) at least one disseminated manifestation (e.g., musculoskeletal, neurologic, or cardiac) plus laboratory confirmation of infection" (Boltri et al, 2002). The disease is caused by a spirochete, *Borrelia burgdorferi*, that, in the northeastern United Sates, is spread by the deer tick *Ixodes scapularis* (Stanek et al, 2012). Nationwide, the disease prevalence has been increasing; there were 17,730 cases of Lyme disease reported in 2000 compared to 29,959 in 2009 (CDC, 2012).

As the disease has spread and increased in incidence, the subject of Lyme disease has become fraught with controversy. There is disagreement on its presentation, whether chronic Lyme is a real phenomenon, what diagnostic tests to use, and how to appropriately treat it. One study found as many as 49% of physicians inappropriately order serologic testing for Lyme when the presence of erythema migrans has already been established (Murray et al, 2001). This same study demonstrated that 26% of physicians administered prophylactic antibiotics for tick bites, a practice that is not routinely recommended.

Lyme disease itself is commonly described as a three stage illness, though some argue this division is more theoretical than practical (Stanek et al, 2012). The first stage consists of flu-like symptoms such as fever, malaise, lymphadenopathy, and body aches. This is also the point during which the tell-tale 'targetoid rash' (erythema migrans) manifests. However, the rash has central clearing in fewer than 35% of cases and is completely absent in 10% of cases (Marques et al, 2010). Thus,

this pathognomonic presentation is a difficult one to rely on for diagnosis. The erythema migrans usually develops within 7-14 days, but may occur as early as the day after infection or up to 30 days post infection (Marques et al, 2010). The rash will typically last for a week or less.

The second stage of the illness occurs from weeks to months after infection and can include meningitis, joint pain, radiculopathies, facial nerve palsy, and carditis with third degree heart block. Cardiac involvement occurs in 4-8% of untreated cases and neurologic involvement in 15-20% (Marques et al, 2010). Many of these symptoms will resolve over weeks or months even in the absence of antibiotic treatment (CDC, 2012).

The third stage may develop months after infection. The symptoms include oligo and monoarthropathies with effusion that can be waxing and waning in nature and may be migratory. These rheumatologic complaints occur in approximately 60% of untreated cases and can occur six months post infection (Marques et al, 2010). Arthritis most often effects the knees and the effusion usually has a cell count of around 25,000/mm^3. As many as 5% of untreated patients will develop chronic neurological complaints months to years following infection, including radicular pain, encephalopathy, paresthesias, and problems with short term memory.

In 10-20% of patients some symptoms persist for years in the form of Post-treatment Lyme disease syndrome (PTLDS) (CDC, 2012). This involves continued joint pain, paresthesias, memory impairment, headache, irritability, muscle pain and other Lyme related symptoms. The cause of PTLDS is unknown, but it is not believed to be due to continued infection by *B. burgdorferi* and occurs despite appropriate antibiotic treatment (CDC, 2012). According to CDC guidelines, continued antibiotic therapy is not beneficial after the first course of treatment and the patients should be managed symptomatically (2012). As with any illness, patients may not adhere to the textbook

description of Lyme; they may skip steps or progress at a different rate.

The subject of Chronic Lyme (which is defined as the persistence of Lyme disease and Lyme disease symptoms due to continuing infection after treatment with antibiotics) is particularly controversial and is not within the scope of this research. However, it is generally accepted that, since *B. burgdorferi* has no resistance to antibiotics, further treatment is not necessary, and symptoms will eventually resolve after initial treatment with no additional intervention needed (Stanek et al, 2012).

The lifecycle of *I. scapularis* is responsible for the spread of disease, its presence in a reservoir host, its spread to humans, the seasonality of infection, and its areas of endemism. Nymphs are active from spring to summer when adults are active. The adult activity continues through winter into early spring though it is diminished during the colder winter months. Reservoirs for *B. burgdorferi* are mostly small mammals such as the white footed mouse. Deer act as a major host for the tick, but do not act as a reservoir for infection. Because of its hosts and reservoirs, infection rates are higher in suburban or rural areas. Although infection can occur year round, late May to late September is the period of increased nymph activity, as well as the times of increased outdoor recreation by people (Stanek et al, 2012).

The distribution of Lyme is centered in the Northeastern United States, Minnesota and Wisconsin (CDC, 2012). In fact, 12 states in this area accounted for 94% of the cases of Lyme disease reported in 2010. In 2009, there were 39,000 cases nationally and the incidence in CT was 78.2/100,000 people, whereas the national rate is only 7.3/100,000 people (CDC, 2012). However, it has been demonstrated that the true rate of Lyme diagnoses may far exceed the CDC reported prevalence (Boltri et al, 2002). In Boltri's study it was found that physicians were under reporting in part due to differing diagnostic standards and approaches. Diagnosis of Lyme disease does occur

throughout the year, but peaks between June and August (Stanek et al, 2012). It affects people of all ages but has a bimodal distribution with peaks in the 45 to 59 and the five to nine year old ranges (Depietropaolo et al, 2005; Stanek et al 2012).

Diagnostic testing for Lyme is straight forward in its own right, but there are numerous testing options, many of which are lacking in credibility or verifiability. It is possible to find a test for Lyme disease using almost any technique on almost any tissue or body fluid sample, ranging from microscopy to PCR and from saliva to skin biopsy. Some of these test kits have demonstrated rates of false positives and false negatives at 30% each (Murray et al, 2001). According to a review of Lyme disease diagnosis by Aguero-Rosenfeld et al (2005), culture is possible of the skin with adequate response, but this takes up to 12 weeks to complete, making it clinically useless. Furthermore, the bacterium can only be isolated in approximately 50% of cases. PCR has been studied on erythema migrans biopsy, serum, CSF, and synovial fluid with sensitivities of 64%, 18%, 73% and 83% respectively. Specificity for these same tissues was 98-100%, 100%, 93-100% and 100%. In this case the only clinical application for PCR is considered to be in the case of synovial fluid. However, as discussed previously, joint effusion occurs at a later stage in disease after seroconversion. The diagnostic test recommended by the CDC (2012) for these cases is ELISA with a reflex Western blot.

Serology has a variable sensitivity depending on the stage of the disease. At the time an erythema migrans develops, serum ELISA with reflex Western blot has a sensitivity of only 38%. It is 67% after an erythema migrans is treated, 87% in cases of neuroborreliosis, and 97% in cases of Lyme arthritis (Aguero-Rosenfeld et al, 2005). Specificity, on the other hand, is close to 99% across all stages of the disease. Specificity for serology alone is only 81% and, for early Lyme, sensitivity is only 59% (Depietropaolo et al, 2005). Seroconversion occurs slowly with Lyme disease and IgM

and IgG antibodies generally appear two to four and four to six weeks respectively after the onset of erythema migrans (Depietropaolo et al, 2005). There are background rates of 4% seropositivity in endemic areas of the United States, further contributing to misdiagnosis when laboratory tests are too heavily relied upon (Stanek et al, 2012).

The Western blot is considered positive if the IgM has two out of three positive bands or if the IgG band has five out of ten positive bands (Aguero-Rosenfeld et al, 2005). Elimination of the preliminary ELISA and simply running a Western blot leads to a significant drop in specificity and may result in misdiagnosis (Stanek et al, 2012). Some labs will consider additional bands, but they lack validity as these have not been studied satisfactorily (Feder, 2008). The exception to ELISA with reflex Western blot is in the case of Lyme meningitis; in these cases ELISA can be used to create an index of the CSF:serum. Though, again, this diagnostic test comes into question because of its low sensitivity (75%) (Blanc et al 2007). For patients in whom erythema migrans has developed, serological testing is not indicated; the diagnosis is purely based on history and physical examination (Stanek et al, 2012).

Tick testing is available, but may be unreliable, is expensive, and provides little clinical value (Murray et al, 2001). Whether a tick is positive or not for *B. burgdorferi* does not change the clinical approach. It is more relevant to simply identify the tick as *I. scapularis*, the sole carrier of Lyme disease in the Eastern United States.

Much like other illnesses, patients in the early stage of disease will not have seroconverted and are likely to have false negative testing. Because of this, much of the diagnosis in these cases is based on patient history and physical examination. Likewise, patients previously exposed to, and treated for, Lyme will continue to have positive serum after treatment and, again, the clinical presentation must be considered more strongly in deciding on a treatment regimen.

Unclear standards combined with confusion and disagreement about the chronicity and presentation of the disease lead physicians down the path of defensive medicine. With the overwhelming options in diagnostic testing and the diverse views on disease progression and treatment, clinicians often select tests that are inappropriate for the situation.

The present study explored how primary care physicians approach diagnosis of Lyme disease in various settings, when they initiate treatment, what their academic knowledge of Lyme is, and their ability to self-assess their knowledge of Lyme disease. It is presently unknown who makes testing and diagnostic mistakes, how they are making them, and to what extent. By improving understanding of this issue the education of health care providers can be better focused on those needing it with a concentration on the specific issues at hand. This would best be carried out in a Plan, Do, Study, Act (PDSA) model in order to orchestrate continuous quality improvement. A better understanding of how and why these tests are being performed can lead to better clinician education. By doing so, fewer unnecessary tests will be conducted, leading to fewer false positives and unnecessary treatment.

It is anticipated that rural physicians will have greater self-assessed and academic knowledge, clinical judgment, and willingness to treat the disease. This is because they are likely to have greater clinical exposure to the disease. This exposure will increase confidence and increase learning of the disease. It will also improve the clinicians' ability to identify cases with a higher index of suspicion and be willing to treat more readily based on history and physical exam instead of relying on laboratory testing. As the disease is relatively new it is not anticipated that there will be a significant difference in the practice of physicians with greater versus less self-assessed experience or years of experience. Overall, it is expected that physicians will perform

poorly with regard to their testing for Lyme disease. In particular, it is hypothesized that they will overuse tests when no test is indicated.

METHODS

An online survey of primary care physicians in Connecticut was conducted in the fall of 2011 to assess their clinical practices and knowledge of Lyme disease. The survey was created using SurveyGizmo (http://www.surveygizmo.com) and distributed via e-mail to the membership lists of the Connecticut Academy of Family Practitioners (CAFP), the Connecticut College of Emergency Physicians (CCEP), the Connecticut chapter of the American Academy of Pediatricians (CT AAP), and the Connecticut chapter of the American College of Physicians (CT ACP). E-mails were sent from the chapters themselves to their own listservs in the form of individual e-mails, not part of a broader message. A second round of e-mails was sent approximately one month later to all groups except the CT ACP which sent only one e-mail.

All responses from the clinicians that identified as a family physican, an internist, a pediatrician, or an emergency physician were included in the analysis. There were no other inclusion or exclusion criteria.

In order to determine their self-assessed level of Lyme knowledge, at the start of the survey participants were asked “On a scale of 0-10 how would you rate your level of clinical judgment of Lyme disease?” A series of clinical vignettes followed and the respondent was asked to select the test option he or she would use to determine a diagnosis of Lyme. The clinical vignettes posited the questions “In your opinion, is laboratory testing for Lyme disease indicated?” and, if yes, “What tests do you feel should be ordered?” The test options provided included most conceivable Lyme tests and a free text space for write-in answers. This was intended to act as an objective

means of evaluating clinical judgment of Lyme disease. All vignettes were based on patients who were 18 to 19 year old males to avoid consideration of significant comorbidities and to make them more accessible to both adult and pediatric providers of care. The six vignettes and their correct answers are as described below.

1. "A 19-year-old man from Old Lyme CT presents with one month of a waxing and waning swollen right knee. He has full range of motion, no fever, and no other symptoms."

This vignette is meant to suggest Lyme arthritis. As discussed previously, the appropriate diagnostic test in this case is a serum ELISA with reflex Western blot. A PCR of synovial fluid would provide an answer with this patient, but has lower sensitivity and is actually not recommended by the CDC for diagnostic purposes.

2. "An 18-year-old man presents with 3 years of fatigue. He denies joint pain or erythema. He has lived his whole life in Hartford. He had a positive Lyme ELISA and a negative western blot 2 years ago."

This patient lives in a non-Lyme endemic area with little risk of exposure, he has no disseminated complaints related to Lyme and has no rash, making a CDC guidelines-based diagnosis impossible. His previous testing demonstrates a false positive ELISA and is not pertinent to his current situation except that it may be used to further argue against a diagnosis of Lyme disease. No testing is indicated.

3. "An 18-year-old man presents with 2 months of fatigue and migrating joint aches. He tells you he is a hunter and picked ticks off his clothes and body during deer season 3 months ago. On exam he has a Bell's palsy but no rash."

This case is meant to represent a case of later Lyme disease. The patient currently

lacks the pathognomonic rash and it was not noted in the past, but does have history of probable exposure and several complaints that point toward Lyme disease. As he has had symptoms for two months, he will have seroconverted already so the best approach is an ELISA with reflex Western blot.

4. "A 19-year-old man presents with muscle aches and rash (seen to the right). He lives in southeastern Connecticut and recalls finding several ticks on his body after a hike 1 week ago. His temperature is 100.3." (A picture of erythema migrans was included.)

This patient is presenting with early Lyme disease. He has symptoms consistent with Lyme and has an erythema migrans. This diagnosis is made in this case based on his history and physical, so further testing is not indicated. It is unlikely he has seroconverted this early, so any testing would run the risk of coming back as a negative due to premature testing.

5. "A 19-year-old man presents concerned after finding a tick attached to his thigh this morning. He suspects he was bitten yesterday while hiking in the woods. He is otherwise well with no other complaints."

In this case the tick may have been attached long enough for transmission to occur so the patient may have contracted Lyme disease. However, seroconversion has not occurred and there is no test available for diagnosing this patient. No testing is indicated.

6. "A 19-year-old man presents concerned he has Lyme. He has a history of ELISA and western blot positive Lyme disease 2 years ago status post treatment with doxycycline. He has fatigue and muscle aches, denies rash, and removed an engorged tick from his leg 4 weeks ago."

Because this patient has a history of positive Lyme disease testing he will, in all likelihood, test positive again regardless of his current disease status. In cases like this, diagnosis must be based on the history and physical. Although testing may reveal positive IgM antibodies implying active disease, a negative result for IgM would be unreliable. Testing will not change the course of treatment, is not indicated and treatment would be initiated regardless of the results.

Those who answered fewer than four vignette questions were not included in the analysis. This eliminated four participants. The summary values for the clinical vignettes ranged from zero (the least clinically knowledgeable) to six (most clinically knowledgeable).

In order to assess the participant's willingness to treat, the above vignettes were each followed up with the question “Would you initiate Lyme treatment at this point, prior to getting lab results back?” This was summed up across the six vignettes, coding “yes” as one and “no” as zero. The willingness to treat summative scale ranged from zero to six with zero being least likely to treat and six being most likely to treat.

A series of ten true/false questions were presented to systematically assess the clinician’s academic knowledge of Lyme disease. The statements and the correct responses were as follows:

1. In Connecticut the only carrier of Lyme is *Ixodes scapularis* (deer tick; black-legged tick) (True)
2. Lyme disease can be transferred to a host within 12 hours of a tick biting (False)
3. After treatment of Lyme disease the ELISA and western blot will be negative

(False)

4. In Lyme disease ELISA is always positive after erythema migrans has developed (False)
5. Lyme-carrying ticks are not active in winter months (False)
6. During the first phase of Lyme disease every patient has erythema migrans (False)
7. *Borrelia burgdorferi* has shown no resistance to conventional treatments (True)
8. Only adult ticks can transfer *Borrelia burgdorferi*, not nymphs (False)
9. Permethrins can be used to help keep ticks out of yards and off of bodies (True)
10. It is possible for some symptoms of Lyme disease to persist for years after treatment (True)

The true/false responses were coded as correct (one) or incorrect (zero) and an academic knowledge scale summed the correct responses. The academic knowledge index ranged from zero (the lowest academic knowledge) to ten (the most academic knowledge). One participant that answered fewer than six true/false questions was excluded from analysis of this variable.

The survey concluded with questions measuring characteristics of the physician's practice. These included: years in practice, medical specialty (Family Medicine, Internal Medicine, Emergency Medicine, or Pediatrics), and community of practice (rural, small town, suburban, or city center).

SPSS was used to conduct statistical analysis of the data. Pearson correlation was used to assess associations between scale measures which included experience, academic knowledge, clinical judgment, willingness to treat, and years in practice.

ANOVA was used to explore the relationship of both specialty and community to the physicians' approach to Lyme. The two independent factors, specialty and community, were studied separately from each other, with the other variable controlled for since a relationship between specialty and community was identified through Chi-square testing ($p<0.0001$). Analyses were based on the number responding to each item.

RESULTS

The survey was sent to a total of 2776 physicians via listerv e-mail. There were 291 total responses, but only 273 completed surveys were received. Overall, the response rates were very low (10%). For CAFP 60/400 (15%) responded, 45/1126 (4%) for CT ACP, 40/450 (9%) for CCEP and 128/800 (16%) for CT AAP. The distribution of specialties was 22% family medicine, 16% internal medicine, 15% emergency medicine and 47% pediatrics. The statewide distribution among these specialties for Connecticut is 13% family medicine, 57% internal medicine, 11% emergency medicine, and 20% pediatrics (Kaiser Family Foundation, 2012).

Six percent of participants had rural practices, 39% practiced in small cities or towns, 26% in suburban areas, and 29% in central cities. The mean number of years in practice of participants was 18.8 years with a standard deviation of 12.2 years. This covered a range of zero to 54 years of practice.

Clinical Knowledge

Overall scores for the clinical vignettes averaged 61% with a median and mode of 67%. Less than ten percent (8%) of participants scored 100%, while 44% scored 50% or less. Details of clinical vignette performance and willingness to treat based on the clinical vignettes can be seen in Table 1.

When presented with the case of a patient with a positive history of Lyme (Case number 6), only 30% of participants selected the correct testing option. Forty percent chose a serum ELISA with reflex Western blot and 24% chose serum Western blot alone. These choices would be optimal for diagnosis in this case, but, as discussed previously, would lack both sensitivity and specificity thus leading to no change in the clinical approach to the patient.

The area in which participants performed best was in the case of the early tick bite. Only 9% of physicians inappropriately chose to perform tests. Also of note, 31% of participants chose to prophylax this patient. Where testing was warranted, participants performed well in knowing to order tests, but not as well with respect to tests they ordered. For the Lyme arthritis case, 91% ordered testing, but only 50% ordered the correct test – serum ELISA with reflex Western blot. An additional 21% ordered the correct test, but also ordered other extraneous tests. For the case of late Lyme disease (Case Number 3), 87% ordered testing and 61% ordered the correct test, which was also serum ELISA with reflex Western Blot. An additional 8% ordered the correct test with extra tests included. In the case of the fatigued patient meant to represent a non-Lyme related complaint, 68% of physicians correctly chose not to test the patient.

The most frequently used test in cases where no testing was indicated was the serum ELISA with reflex Western blot. Additionally, serum ELISA and serum Western blot ordered either alone or in tandem were also frequent incorrect answers in these cases. In the case of Lyme arthritis where serum ELISA with reflex Western blot was indicated, incorrect responses included no testing (9%), PCR of synovial fluid (12%), serum Western blot (12%), synovial fluid ELISA with reflex Western blot (11%), synovial fluid culture (11%), serum ELISA (8%) and synovial fluid microscopy (8%). For the case of late Lyme disease, the most frequent incorrect responses given were serum Western

blot (14%) and serum ELISA (10%) either alone or together not as reflex and serum PCR (5%).

Clinical judgment was inversely correlated with the physician's willingness to treat (P=0.016, r=-0.143), indicating that physicians with greater clinical acumen are less inclined to order treatment without test results. Self-assessed knowledge positively correlated with academic knowledge (P=<0.001, r=0.217) and self-assessed experience (P=0.043, r=0.118), but demonstrated no relationship to the number of years of practice, specialty, or community.

Table 1: Primary Care Physicians' Diagnosis and Treatment of Lyme Disease: Connecticut, 2011

Case subject	Lyme Arthritis	Non-Lyme	Late Lyme	Early Lyme	Tick Bite	Positive Lyme History
Made the correct diagnostic choice	50%	68%	61%	61%	91%	30%
Opted to test for Lyme disease	91%	32%	87%	39%	9%	70%
Would treat prior to receiving test results	29%	2%	83%	93%	4%	40%
Would prophylax prior to receiving test results	2%	0.3%	1%	1%	31%	3%
Total treating	31%	3%	83%	94%	35%	43%

Academic Knowledge

The data regarding academic knowledge is found in Table 2. The mean score for academic knowledge was 76% with a standard deviation of 15%, the median and mode were 80%. Nine percent correctly answered all true/false questions, while 10%

answered 50% or fewer correctly.

Almost all (99%) physicians correctly responded that not all Lyme cases develop erythema migrans and that an ELISA and Western blot would not necessarily be negative after treatment of disease (96%). Most (89%) also correctly answered that ELISA is not always positive when erythema migrans is present and that ticks are not only active in the winter (80%). However, only half (52%) of respondents knew that *B. burgdorferi* has no demonstrated resistance to treatment. On the question regarding *Ixodes scapularis* being the sole carrier of Lyme disease in Connecticut, 64% of physicians answered correctly. The question on transference of Lyme disease after only 12 hours was correctly identified as false by 70% of participants. Permethrins were correctly chosen as a viable tick repellant by 69% of respondents. Two-thirds (67%) of participants correctly responded that some symptoms of Lyme disease can persist for years post treatment.

Academic knowledge correlated significantly with self-assessed experience (P=<0.001, r=0.232), with years in practice (P=0.001, r=0.201), and with community population density (P=0.005, η^2=0.05), but had no relationship with specialty or willingness to treat.

Table 2: Primary Care Physicians' Academic Knowledge of Lyme Disease: Connecticut, 2011	
1. In Connecticut the only carrier of Lyme is *Ixodes scapularis* (deer tick; black-legged tick) (True)	64%
2. Lyme disease can be transferred to a host within 12 hours of a tick biting (False)	70%
3. After treatment of Lyme disease the ELISA and western blot will be negative (False)	96%
4. In Lyme disease ELISA is always positive after erythema migrans has developed (False)	89%

5. Lyme-carrying ticks are not active in winter months (False)	80%
6. During the first phase of Lyme disease every patient has erythema migrans (False)	99%
7. *Borrelia burgdorferi* has shown no resistance to conventional treatments (True)	52%
8. Only adult ticks can transfer *Borrelia burgdorferi*, not nymphs (False)	73%
9. Permethrins can be used to help keep ticks out of yards and off of bodies (True)	69%
10. It is possible for some symptoms of Lyme disease to persist for years after treatment (True)	67%
Percent correct across all specialties and communities	

Self-assessed knowledge

On average, physicians rated themselves as having only a moderate level of experience (6.8/10, sd=2.0) with Lyme disease. This covered a range of 0 to 10 and the mode was 8. Self-assessed experience correlated with years in practice (P=<0.001, r=0.265), but not with willingness to treat.

The results of the correlation and ANOVA can be seen in Tables 3 and 4 respectively.

Table 3: Associations Among Variables Measuring Primary Care Physicians' Knowledge and Practice Regarding Lyme Disease, Connecticut 2011

	Experience	Academic Knowledge	Clinical Judgment	Willingness to Treat	Years in Practice
Experience	1.0				
Academic Knowledge	P=<0.001† r=0.232	1.0			
Clinical Judgment	P=0.043* r=0.118	P=<0.001† r=0.217	1.0		

Willingness to Treat	P=0.675	P=0.851	P=0.016* r=-0.143	1.0	
Years in Practice	P=<0.001† r=0.265	P=0.001† r=0.201	P=0.603	P=0.668	1.0
* significant at p=<0.05 † significant at p=<0.01					

Table 4: Primary Care Physicians' Knowledge and Practice Regarding Lyme Disease by Specialty and Community Type: Connecticut, 2011

	Specialty‡	Community§
Academic Knowledge	P=0.452	P=0.005† η^2=0.05
Clinical Judgment	P=0.081	P=0.887
Willingness to Treat	P=<0.001† η^2=0.115	P=0.248
Willingness to Test	P=0.128	P=0.124
Experience	P=0.508	P=0.011* η^2=0.043
* significant at p=0.05 † significant at p=0.01 ‡ controlling for community § controlling for specialty		

DISCUSSION

Although physicians had areas in which they demonstrated poor clinical judgment, there were cases, such as that of the tick bite, in which they performed quite well. Rates of prophylaxis and treatment varied widely depending on the case presentation, with emergency medicine physicians being most likely to administer medications. Conversely, those physicians with better clinical judgment had lower rates of treatment. Rural physicians performed better than those from more populated areas when it came to academic knowledge, though specialty had little bearing on academic knowledge or clinical judgment.

The low response rate in this study raises questions of validity. A similar study conducted by Murray et al (2001) had a response rate of 55.8% using mailed surveys. This low response rate in the present study may simply be due to the nature of e-mail based surveys in that they are more easily ignored than a letter with a pre-stamped envelope. Or it is possible that responses were biased toward physicians with a stake in Lyme disease, perhaps physicians on either side of the 'chronic Lyme' argument, or those who more frequently see cases of Lyme disease. This low response rate raises concerns about external and internal validity. It should be noted, however, that the membership lists of the four professional associations may have included some duplicates if any primary care physicians were members of more than one of these groups. Also, the membership lists may have included physicians who were no longer in practice. Thus, the actual response rate may have been slightly higher than the 10% reported for the study.

However, it should be noted that similar findings to that of Murray et al were found where survey questions overlapped. Both studies found similar rates of testing by physicians for patients presenting with erythema migrans (i.e., 49% for Murray et al and 39% in this study). Murray and his colleagues found that 88% of physicians started treatment without test results, while this study found 94.3% of physicians started treatment. Twenty-six percent of respondents in their study started prophylaxis for tick bites, while this study found 30.8% of clinicians did so. These similarities provide some reassurance that the results of this study are valid.

We found that physicians do have rather poor performance when it comes to the diagnosis of Lyme disease. This was particularly notable in the vignette of the patient with a positive history of Lyme disease and in the case of the patient with Lyme arthritis. On the other hand, in the case of the tick bite 91% of participants correctly chose to

perform no diagnostic test. Thirty-one percent of participants chose to prophylax the tick bite patient, compared to prophylaxis rates of 3% or less for other cases. This raises questions of over or underprophylaxing patients following tick bites. In this case the risk was rather low, but Warshafsky et al (2010) have demonstrated that prophylaxis can reduce risk of Lyme disease infection from 2.2% to as little as 0.2%. This may warrant further study using more in depth vignettes to give a more accurate presentation of risk of infection. In this study simple vignettes were chosen with minimal detail to avoid confounding factors. More realistic cases with more detail would likely result in more educated decisions by physicians and a greater ability to determine the index of suspicion for disease and whether they feel prophylaxis is warranted.

It appears that physician specialty has little bearing on their knowledge – clinical or academic – of Lyme disease. Emergency medicine physicians demonstrated a significantly greater willingness to treat prior to receiving test results. This is most likely due to the nature of their practice in that they have a greater risk of losing patients to follow up. Family physicians were also more likely to treat than internal medicine or pediatric doctors, but to a lesser extent than emergency medicine physicians. This may be secondary to some of them working in urgent care settings instead of purely in outpatient primary care clinics.

The community of practice was related to academic knowledge and to self-assessed experience, but not to clinical judgment. It may be that rural physicians performed better in academic knowledge because of greater clinical experience with Lyme disease. However, one would expect better performance in clinical diagnosis if this was the case. This may be explained by a greater index of suspicion by rural doctors for Lyme disease, leading to a greater propensity to run diagnostic testing. In order to tease out the reasons for this difference it would be important to determine the

assessed pre-test probability determined by the participant for each case. Rural doctors also reported a greater level of self-assessed experience, likely due to greater exposure to patients with Lyme disease in their community of practice.

Performance on clinical vignettes was inversely related to willingness to treat, suggesting that greater clinical judgment led to lower rates of initiating treatment prior to receiving test results. This likely demonstrates a greater level of confidence in testing and in assessing the pre-test probability of disease. Clinical judgment was correlated with academic knowledge as expected. However, doctors with greater experience had greater clinical judgment as well as academic knowledge.

Willingness to treat demonstrated no relationship to academic knowledge, self-assessed experience, or years in practice. It was only affected by specialty and clinical judgment, as discussed above.

Although the use of inappropriate testing is not unique to the diagnosis of Lyme disease, it is a clear area of concern. This type of approach to medicine can result in unnecessary treatment, expenditure, and inaccurate data on the disease itself. Further research would be needed to adequately assess this. As it stands, these data can be used to evaluate the efficacy of interventions on physician practice and to direct said interventions toward doctors in an effective manner.

The costs associated with incorrect diagnostic testing were not assessed by this study, but exploration of these issues in future study would be valuable. With 8% of physicians reporting they often order tests due to patient desire and not because of clinical indication and 73% reporting they sometimes order due to patient desire, it is clear thatdoctors are likely to be ordering unnecessary tests. It is possible to rectify the use of incorrect tests with education, but it is a different issue to correct this type of practice error.

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