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Implementation of Point-of-Care Tick-Borne Disease PowerPlan™ and algorithm for early detection and treatment of tick-borne diseases

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Implementation of Point-of-Care Tick-Borne Disease PowerPlan™ and Algorithm for Early Detection and Treatment of Tick-Borne Diseases.

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Dedication

How grateful am I for the ability to dedicate my forthcoming doctoral degree to my husband, mother, and father. Robert, never was there a falter in your persistence, and it is this persistence that has opened up so many doors, as this educational path has for me. To Diane and Alan, never was there a falter in your support throughout my life and educational career, I would not be where I am if it were not for the both of you. From the deepest parts of my being, thank you.

Abstract

Local Problem: The Concord Hospital system, serving 30+ communities, is situated in the heart of New Hampshire surrounded by densely wooded forests, lakes, and mountains and is a mecca for camping, vacationing, and sightseeing, doubling its population of 1.6 million residents during spring, summer, and fall months. Despite the serenity, there is a predator that lingers among the hiking trails and lake shorelines. From January 2021 through August 2022 there were a total of 41 hospitalizations from tick-borne diseases, some with life threatening symptoms. Unfortunately, nearly half (43%) of patients presented to their primary care provider first where the diagnosis was missed.

Background: Despite their minute size, ticks including the black-legged tick *Ixodes Scapularis*, are known to harbor a plethora of bacterial and parasitic disease states. As diseases such as *Babesiosis* are on the rise not only in locally but nation-wide, it is imperative that front-line providers not only understand various clinical presentations but have point-of-care tools to accurately diagnose and promptly treat patients, as delays in care may have lethal consequences. The global aim of this quality improvement project was to improve provider recognition of symptoms, appropriate diagnostic testing, and treatment associated with tick-borne illness. Specifically, we aimed to increase provider awareness by 20%. Additionally, our second specific aim was to develop, and improve upon point-of-care resources for clinicians, increasing overall PowerPlan™ utilization by 40%.

Methods: Utilizing the six aims of a healthcare system quality improvement initiative put forth by the Institute of Medicine (IOM) and backed by the Agency for Healthcare Research and Quality (AHRQ), as well as Kurt Lewin’s Change Theory, and the Plan Do Study Act (PDSA) method of quality improvement, we evaluated baseline clinician knowledge of tick-borne diseases prior to delivering education and point-of-care resources for providers.

Interventions: A lunch and learn educational PowerPoint™ presentation was delivered to providers at three practice locations, and one student group at Concord Hospital Laconia. A pretest and posttest format was utilized to assess the baseline knowledge of tick-borne disease symptoms, appropriate diagnostics, and treatment prior to the presentation. Edits were made to the existing Tick-Borne Disease PowerPlan™ and a user-friendly tick-borne disease algorithm was created as point-of-care tools for providers to utilize with patients meeting potential illness criteria. Utilization of the PowerPlan™ was queried pre-post intervention.

Results: Total aggregate data sample size was 13, although for statistical analysis using Wilcoxon signed rank testing, only seven pairs were able to be matched for comparison. Despite a small sample size, there was a statically significant change in test scores prior to the educational session when compared to after, z=2.379, p=0.017. When specific disease states were analyzed, there was a statistically significant increase in knowledge of *Babesiosis*, z= 2.232, p=0.026. Statistical significance was also observed with respondents ordering correct laboratory studies when presented with a tick-borne disease case presentation, z= 2.0, p=0.046. Despite partial data from March 2023, there was an increase in PowerPlan™ utilization with 83 access points compared to 64 in March 2022.

Conclusion: The key finding of our quality improvement project was incongruencies between perceived knowledge and actual knowledge of various tick-borne illnesses both in pre-licensure 3rd year medical students and practicing clinicians. Through enhanced educational interventions utilizing emerging epidemiologic trends, as well as creating an accurate and trusted point-of-care algorithm, we were able to decrease this knowledge gap. By providing interactive educational training and user-friendly point-of-care resources for front-line clinicians nation-wide, they will be poised to accurately diagnose and treat complex tick-borne diseases at the first symptom, preventing the potential grim sequela of a missed diagnosis.

Keywords: Tick-borne disease, *Babesiosis*, Provider knowledge, Point-of-care resource, Quality Improvement

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Introduction

Controversy. Unlike what we have all witnessed over the past two years, tick-borne diseases were identified over a century ago, and continue to be an emerging threat that remains controversial. The first identification of the tick as a vector of transmissible disease was reported by Smith and Kilbourne (1893) as a result of their work in Texas. A mysterious disease was identified by farmers and stock owners and caught the attention of the government in the 1800's recognized as *Texas Fever*, or *Southern Cattle Fever*. Characteristics of the disease included appearing in the warmer season, only on those cattle who passed over the same southern territory, it was not passed within the herd, and lastly the disease was acute with severe destruction and death (Smith & Kilborne, 1893). Initially experimentation with bacterial sources of infection took place, however it was not until Smith & Kilborne identified the protozoal microorganism, *Babesia bigemina*, in the blood corpuscles of the farmers and stock owners that fully explained the transmission and destructive effects of the disease.

Where Smith & Kilborne led the way identifying the tick as a vector of disease in cattle, Ricketts successfully inoculated guinea pigs and monkeys with spotted fever in 1906, and just a few short months later in conjunction with Ricketts, King & Schwan (2006) published the short, but astounding paper in the Public Health Reports implicating the wood tick in the transmission of spotted fever in human disease. This disease later named after Ricketts, *Rickettsia rickettsia*, better known as Rocky Mountain Spotted Fever, was the sentinel discovery and underpinnings of the ever-growing epidemic of tick-borne diseases (Eisen et al., 2017).

Seventy years later, physicians and researchers alike were again puzzled by clusters of symptoms identified in humans, on both the west and east coasts. A rash, known as *erythema chronicum migrans* (ECM), followed by arthritis, in association with fevers, malaise and fatigue, headache, among other symptoms, appeared in the summer months in Lyme, Connecticut in 1975 and concomitantly in Sonoma, California. Cases also were reported in Long Island, New York as well as parts of Europe which sparked collaboration among researchers including Burgdorfer, Lennhoff, Benach, Lane, Gresbrink, culminating in the discovery of the spirochetal disease known as Lyme disease, and transmitted via not only the eastern black legged tick, *Ixodes scapularis*, but the western black legged tick, *Ixodes pacificus* (Eisen et al., 2017).

Dr. Burgdorfer and colleagues were able to isolate the spirochete from the midgut of the black legged tick by indirect immunofluorescence as well as by western blot analysis of sera, confirming saliva and regurgitation as the mode of transmission to humans. Parallel to the discovery of Lyme disease (*Borrelia burgdorferi* named after Dr. Burgdorfer), was the discovery of human *Babesiosis* first identified in a Croatian farmer in 1957, followed closely by the discovery of *Babesia microti* in humans in Nantucket with sporadic cases reported in Martha's Vineyard, Shelter Island, New York and Montauk, New York in 1976 and 1977 respectively (Montero et al., 2022; Telford et al., 2021).

Where cases after initial discovery seemed to be local, it became apparent that like the Texas cattle herd, ecological and environmental factors were identified throughout the Northeast as well as North-Central regions of America. Reforestation and rebounding deer populations during the second half of the 20th century yielded ecological conditions that were conducive for the spread of *I. scapularis* (Eisen et al., 2017). This coupled with the growing population and demand for housing brought humans closer to rural areas where the hosts (deer, mice, rodents, among others) and tick vector merged.

The lifecycle of *Ixodes scapularis* includes four stages: egg, larva, nymph, and adult. In the later three stages typically during the spring, summer, and fall months, the vector is able to transmit disease, therefore, seasonality also appeared relevant corresponding to the life cycle of the black legged tick. Initially, more cases had been reported in warmer months, however as global warming trends have continued, vector-borne diseases such as Lyme disease and *Babesiosis* are being diagnosed year-round. Furthermore, not only are new patterns emerging, but also new tick-borne diseases such as *Anaplasmosis*, *Ehrlichiosis*, and Powassan Virus Disease among others.

Problem Description

In recent decades, the number of reported cases of notifiable tick-borne diseases has steadily increased, and ticks have been identified in nearly 95% of all reported vector-borne diseases according to the CDC (Adams et al., 2014). Locally we have seen similar increases in the cases of *Anaplasmosis*, *Babesiosis*, as well as the emergence of Powassan Virus disease. In 2019, there were over 300 cases of *Anaplasmosis* reported, where previous years barely peaked 100, likewise in 2021 there were 79 cases of *Babesiosis* reported compared with 28 the year prior (NH DHHS, 2022). Furthermore, not only were cases reported in spring and summer months, but cases of Lyme disease, *Anaplasmosis*, and *Babesiosis* were reported well into November, December, as well as the winter months (NH DHHS, 2022). Many of the cases reported fall within the catchment area of the community hospital group which encompasses thirty communities and five out of the ten New Hampshire counties (NH DHHS, 2022).

From January 2021 through August 2022 there were a total of 126 hospitalizations, observational stays, and emergency room visits with diagnosis codes equating to a tick-borne disease at Concord Hospital. Out of the 41 hospitalizations, over 60% were *Anaplasmosis* related, where the other 39% were diagnosed with *Babesiosis* or Lyme Disease, leaving the remaining 1% due to *Ehrlichiosis* or relapsing fever. In reviewing the cases, 43% of patients initially had encounters at their primary care office, urgent care, or had an emergency room visit prior to their admissions.

This rising trend is multifactorial including advances in diagnostics, however even with advances in diagnostic testing many cases are not diagnosed in a timely manner leading to serious consequences, furthermore, it is also well known that the actual number of Lyme and other tick-borne disease is drastically underreported. Data relies on factors including severity of disease symptoms which would trigger patients to seek care, knowledge of the healthcare provider to suspect possible tick-borne disease subsequently leading to accurate test requisition, and finally, reporting the diagnosis to state and national public health authorities.

Available Knowledge

Primary care providers caring for members of our community will encounter patients suffering from the effects of tick-borne illnesses and a standardized approach is necessary. This approach should include critical elements of the history and physical exam, laboratory and diagnostic testing, referrals when necessary and an interdisciplinary approach to the plan of care.

Gold-standard testing to detect tick-borne disease includes testing by polymerase chain reaction (DNA-PCR) and serology, including the well-known western blot. These are typically sent out to specialized labs and unfortunately can take upwards of two weeks to be reported. The test methods are also controversial for a few reasons. First, when antibody testing is performed early on or later in infection false negatives may result. Second, antibody response has been shown to wane or persist regardless of disease state (acute or latent). Lastly, a positive diagnosis encompasses the patients’ clinical symptoms in conjunction with the appropriate diagnostic testing, therefore education of the provider to accurately recognize key factors in early disease is crucial.

Despite improved resources many cases are diagnosed in the hospital due to progressive symptomatology and sequala of delayed diagnosis. In both *Babesiosis* and *Anaplasmosis*, the pathophysiology is similar where *Babesia microti* invades and lyses the red blood cell, *Anaplasma phagocytophilum* invades and triggers neutrophil degranulation. These mechanisms can lead to mild symptoms such as fever, headache, chills, and myalgias, to pancytopenia, acute respiratory distress syndrome (ARDS), congestive heart failure, renal failure, disseminated intravascular coagulation, shock, and coma (Krause, & Vannier., 2021).

In 2021, Mattoon et al., queried current knowledge of, perceived challenges, and needed resources of primary care and emergency and urgent (frontline) healthcare providers practicing in a small-town community endemic to Lyme disease with emerging incidence of additional tick-borne diseases (*Anaplasmosis*, *Babesiosis*). They found that where most providers felt moderately knowledgeable regarding Lyme disease symptoms & treatment, a sizeable proportion lacked knowledge on symptom detection, appropriate diagnostics, and treatment of *Anaplasmosis*, and none reported they were extremely knowledgeable on clinical management of *Babesiosis* (Mattoon et al., 2021). This was also demonstrated in the work by Hill and Holmes in 2015, where mailed surveys to primary care providers in Arkansas revealed an opportunity for education related to basic understanding of Lyme disease (LD) transmission, LD symptoms, evidentiary diagnostic tools, and required reporting practices.

There are currently multiple prevention efforts underway by various state and national organizations to help reduce the increasing cases of tick-borne diseases. These strategies include vaccines, which can take many years to develop, as well as environmentally based control methods and personal protective measures. Environmental based strategies are cumbersome and given the wide range of hosts, as well as ubiquitous nature of the vector, have largely failed in previous attempts. Personal protective strategies including using tick repellent, wearing permethrin impregnated clothing, and avoidance of habitats where ticks are prevalent are campaigns by the Centers for Disease Control as well as state departments of health, however despite these efforts' cases continue to rise. Given the alarming trend coupled with the potential serious sequela of *Babesiosis* and *Anaplasmosis*, it is clear there needs to be a focused effort at the local level to rapidly identify and provide timely treatment of suspected tick-borne diseases.

Rationale

The mission and vision of Concord Hospital is that they are a charitable organization which exists only to meet the health needs of individuals within the communities it serves (Concord Hospital, 2022). The list of values among the organization includes continuous quality improvement, leadership, stewardship, and above all else patient-centered care. Concord Hospital receives its national accreditation from Det Norske Veritas (DNV) healthcare which integrates the ISO-9001 quality management system with Medicare hospital standards.

As outlined above, nearly half of the patients within Concord Hospital catchment area with acute symptoms related to tick-borne diseases made initial efforts to seek care outside of the hospital itself. Unfortunately, despite their attempt, they ended up hospitalized. In a recent study by Slunge and colleagues (2022) out of Sweden, they found that patients with tick-borne disease, in particular encephalitis which can be a late manifestation of disease, were hospitalized longer than a comparison cohort within the first year of the illness, logged more specialist outpatient visits, and used more sick leave days. In observations among hospitalized patients with the diagnosis of *Babesiosis* and *Anaplasmosis* at Concord Hospital, average length of stay was 4 and 6 days respectively.

Framework

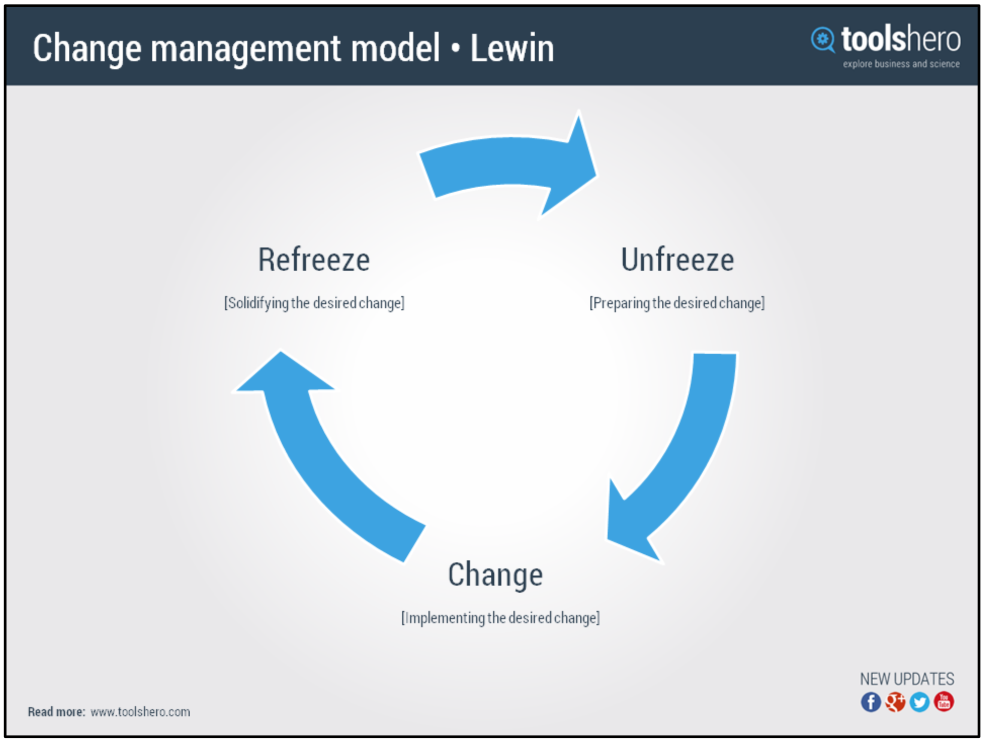
Keeping with the mission and vision of Concord Hospital as well as incorporating the national strategy to transition healthcare to value-based medicine, it is integral to utilize a quality improvement framework which has the patient at the core of its model. The quality improvement initiative put forth by the Institute of Medicine (IOM) and backed by the Agency for Healthcare Research and Quality (AHRQ) includes six aims of a healthcare system. The framework is structured first around patient safety, followed closely by scientifically driven effective care. It is patient-centered and timely to reduce harmful delays, and finally is efficient and equitable avoiding waste within the system and for the patient, while providing care that does not vary in quality (IOM, 2001). These aims came out of the groundbreaking report *Crossing the Quality Chasm: A New Health System for the 21st Century* released in 2001 which identified the need for a whole system change to close the divide on what we know to be quality healthcare verse the current state of healthcare delivery. Patients within the Concord Hospital catchment are currently not only at risk epidemiologically due to increased presence of ticks and tick-borne illnesses, but also face potentially ineffective care within our system.

To many, the word change brings about many different emotions, thoughts, and sometimes even fears. The COVID-19 pandemic was a dashing example of change, many would argue change for the worse, but others would say for the better. The pandemic highlighted gaps within the healthcare system (Blumenthal et al., 2020), but also forced rapid change (Shah, Pereira, & Tuma., 2021). As an example, telehealth, a concept that was in its infancy, was catapulted into the limelight. Many providers were moved to change how they interacted with patients in order to still effectively deliver quality care. This meant not only learning new technologies, but also expanding upon communication skills to aide in determining a diagnosis, since basic assessment principles such as auscultation could not be performed through the screen. The pandemic captured the utility of small, but rapid tests of change.

Kurt Lewin, psychologist and pioneer of behavior change theories, understood that behavior was shaped not only by innate tendencies, but also by environmental and life experiences. He understood the gravity of momentum building and action research to effect change. In his three-step model (Figure 1), Lewin first identifies the reason change is needed. Additionally, within this first step, ‘unfreezing’, he outlines the need to gain support for the change and determines the plan for a successful change. Next, in the ‘change’ or ‘moving’ phase, he points out the need for knowledge sharing and communication, while dispelling rumors that may bring about negative attitudes or undermined the project goals, this stage utilizes momentum and action research (James et al., 2016). Finally, the third stage seeks stability of the change, or symbolizes the return to equilibrium and is titled the ‘freezing’ phase. By utilizing Kurt Lewin’s Change Theory (James et al., 2016), we will be able to analyze the current level of provider understanding with relation to tick-borne illnesses, while communicating the need for change in the unfreezing stage. This will be followed by directed provider education as well as implementation of a specific tick-borne disease care-set and algorithm in the moving stage, followed by feedback and evaluation in order to sustain long-term success, ‘freezing’, in efforts to improve patient-centered effective care.

Figure 1

Lewins’ Change Management Model



Note: From www.toolshero.com

Global Aims

Despite modern advances with send-out testing for confirmatory diagnosis, tick-borne diseases can be identified by basic laboratory testing coupled with patient symptomatology. Not only are these basic tests available in any laboratory across the country, the turn-around time is hours vs days which can reduce delays in care, expediting appropriate treatment, and avoiding possible harmful outcomes or unnecessary hospital stays. The global aim of this quality improvement project is to improve provider recognition of tick-borne illnesses in the outpatient setting to curb delays in treatment leading to hospitalization and sequalae of disease progression.

Specific Aims

This quality improvement project is being conducted specifically to:

1. Increase provider awareness of symptoms as well as appropriate diagnostic testing associated with tick-borne illness at three selected outpatient locations by 20% starting November 2022 and ending March 2023,
2. Improve upon the current Tick-borne Disease PowerPlan™ to include a user-friendly algorithm incorporating basic laboratory testing with same-day results to help guide and initiate timely treatment, with goal of 40% increase in PowerPlan™ utilization starting January 2022 and ending March 2023.

Methods

Context

Concord Hospital, Concord, is a 295-bed facility situated in the center of New Hampshire serving over 30 communities. It is a level two trauma center, and recently became a regional transfer center. As of 2021, Concord Hospital acquired the former Lakes Region General Hospital and Franklin General Hospital expanding the catchment area and bed capacity by 162 available beds. Within this system there are additionally eighteen outpatient clinics and one walk-in urgent care.

The topography and landscape of central New Hampshire is largely rural with approximately 84% of its 5.75 million acres forested (Smith & Anderson, 2022). Hiking is one of the most popular pursuits among New Hampshire residents and visitors with multiple State Parks, and nature reserves including Bear Brook State Park a 10,000 acre preserve located within Concord Hospital catchment, as well as the Belknap Mountain Range in Laconia and Gilford. New Hampshire is also a mecca for camping, vacationing, and sightseeing, doubling its population of 1.6 million residents during spring, summer, and fall months. For *Ixodes* *scapularis*, the sprawling deciduous forests consisting of oak and maple trees, tall brush, fields, as well as leaf litter coupled with the expanding population of white-tailed deer, rabbits, mice, squirrels, and other rodents of New Hampshire provides the ideal habitat to thrive.

Taking into consideration the expansion of our catchment area, topography and landscape of New Hampshire, swelling tourism population, and life cycle of the black-legged tick aligning with the months of highest tourism, it is imperative that Concord Hospital and its affiliates have guidelines in place to address and treat tick-borne illnesses.

Cost-Benefit Analysis

Through utilizing cost estimate data from Concord Hospital Billing department (2022), a moderate complexity emergency room visit with a CPT Code of 99283 at Concord Hospital on average is $1,152.00. Initial hospital consultation and admission ranges from $314.00 to $639.00 with CPT Codes of 99221-99223. Subsequent visits while patient is hospitalized range from $124.00 to $330.00 with CPT Codes of 99231-99233. The base average including room and bed charges at Concord Hospital is $2,120.00 per day. This does not take into account intravenous (IV) associated charges, additional labs, or specialist charges. Hospitalization of a tick-borne illness can vary as identified by Slunge et al (2022) but can be quite lengthy at upwards of eleven days. In analyzing the current data at Concord Hospital from January 2018 through August 2022, the mean length of stay for tick borne diseases using diagnosis codes equating to *Anaplasmosis* (A79.82), *Babesiosis* (B60.0), *Ehrlichiosis* (A77.40), and Lyme Disease (A69.20) was 4 days. A four-day admission for a patient with tick-borne disease would cost approximately $8,480 (without labs, IV charges, or specialist fees).

Currently, the cost for a primary care visit for an established patient without insurance ranges from basic complexity with a CPT Code of 99212 $105.00, to high complexity with a CPT Code of 99215 equating to $433.00 (Aziz, 2022). Laboratory testing is offered in five locations within the Concord Hospital catchment, making same day testing feasible for patients. Utilizing current rates for a patient without insurance it would cost a total of $790 to receive a complete blood cell count with differential, complete metabolic panel, acute tick-borne disease panel, and Lyme antibodies, which are three basic tests that can aide in early detection of tick-borne diseases. If there were abnormalities on the screening leaning towards confirming suspicion for Babesiosis or Anaplasmosis a blood parasite smear could be added on for an additional $669.00. If Lyme disease antibodies are positive at Concord Hospital a Western Blot is reflexed out for an additional fee of $168.00. For a patient without insurance paying for testing alone with abnormalities which incurred reflexed testing the total cost would come to $1,627.

For the uninsured patient who sought care at their primary care department with symptoms aligning with acute tick-borne disease, and the provider utilization of the tick-borne disease care-set which would include basic labs (CBC, CMP, Lyme Antibodies, Tick-Borne Disease Panel) the patient would pay approximately $1,059 (taking the average of basic complexity to high complexity CPT code value). In contrast, if the patient was to present to the emergency room and go onto be admitted they would be looking at a minimum of $2,910 which would include basic daily labs and IV charges. If this patient was to stay the mean length of 4 days, the cost for their illness would be approximately $11,640.00, an increase of ten-fold when compared to the outpatient pathway. Schwartz and colleagues (2020) found similar results in their analysis of Lyme disease related hospitalizations from 2005-2014 with the mean length of stay of 3.5 days, and median cost of $11,688.

Interventions

Three primary care practices were selected out of the Concord Hospital catchment including a primary care location to the north of Concord, a family medicine practice located just east of Concord, and lastly a family practice located to the west of Concord. This disbursement allowed for data to be captured across the community and allowed for engagement of the targeted provider population including medical doctors (MD/DO), nurse practitioners (NP), and physician assistants (PA). The team was also comprised of members of the clinical informatics department, practice managers, a clinical agency stakeholder, medical librarian, inpatient document analyst, as well as a University of New Hampshire faculty mentor.

Pre-Post Test Knowledge Assessment

A pretest and posttest format was utilized to assess the baseline knowledge of tick-borne disease symptoms, appropriate diagnostics, and treatment prior to a lunch and learn PowerPoint™ presentation. The survey was be completed using the Qualtrix ™ software allowing for electronic submissions. Demographic data included years of experience, and role (MD, NP, PA). Rationale being experienced providers may not have had basic medical education on tick-borne illnesses, nor have they received continuing education since entering practice, furthermore in identifying role, we would be able to better understand if there is a gap in education between three possible routes of entry into medicine. To keep anonymity, but allow for matched comparison, providers were asked to select and remember a random four-digit number to their liking. A post-test with the same number of questions was administered two weeks post educational session to determine retained knowledge, with three additional questions pertaining to any change in practice after receiving the education. Test question format was multiple choice with one point allotted to correct scores, with the more questions correct equating to a higher overall score.

Tick-Borne Disease PowerPlan™ & Algorithm

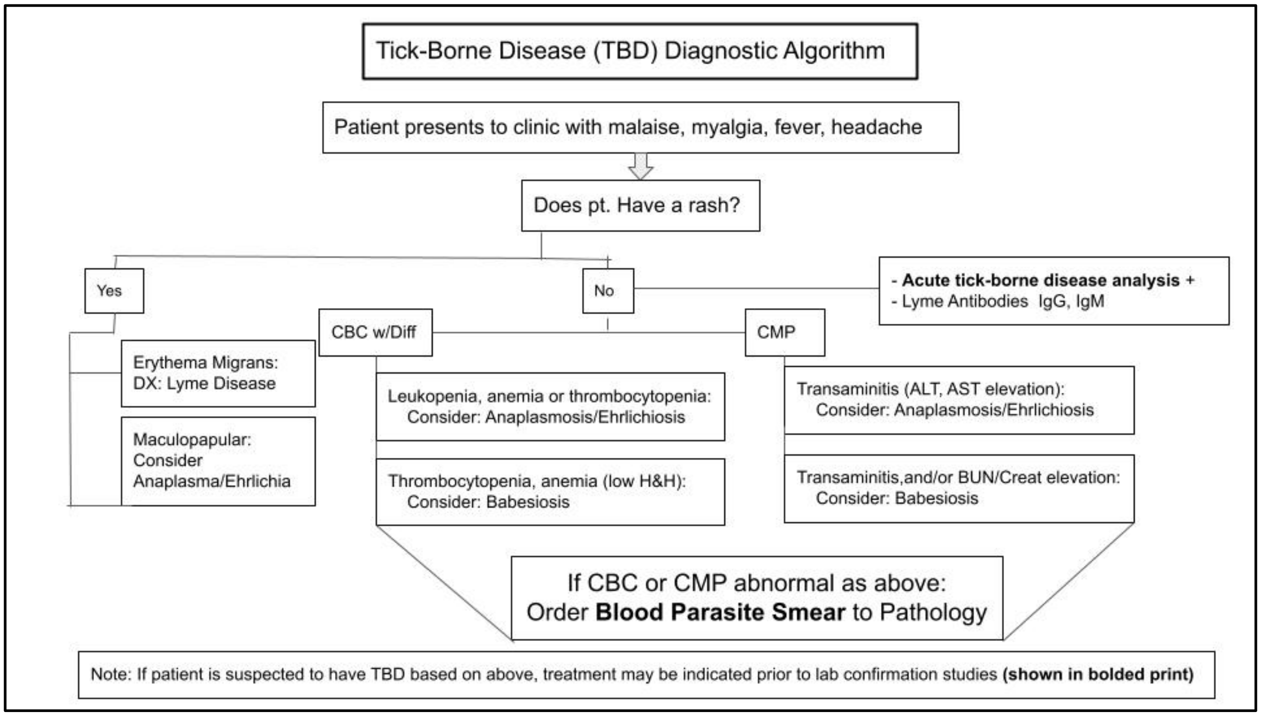
Concord Hospital utilizes the Cerner™ electronic health recording platform which allows for grouped care-sets called PowerPlans™. A PowerPlan™ is a care planning tool that allows providers the ability to manage orders, outcomes, and interventions as they relate to an individualized patient-specific, problem-driven plan of care (Cerner, 2022). Currently there is a tick-borne disease PowerPlan™ that includes only two laboratory items: the acute tick-borne disease panel and Lyme antibodies. Through working with the clinical nursing informatics manager, a key stakeholder for Concord Hospital IT and Cerner™ build team, the second intervention was to expand upon this PowerPlan™. A query on utilization of this PowerPlan™ was performed pre-and post-intervention.

We first created a Concord Hospital specific Tick-Borne Disease algorithm (Figure 2) based upon the algorithm published by the Dutchess County Department of Health and originally adopted from New York State Department of Health's Diagnosing Tick Borne Disease flyer, Massachusetts Department of Public Health Tick-borne Disease Physician's Reference Manual, and the Centers for Disease Control and Prevention's Tickborne Diseases of the United States: A Reference Manual for Health Care Providers (Appendix A).

Modifications to the original algorithm included removal of rocky mountain spotted fever and tularemia, as well as indication to initially order blood parasite smear. The option to add blood parasite smear was identified if the screening CBC w/diff was positive for neutropenia, thrombocytopenia, or anemia, and/or transaminitis found on CMP.

Figure 2

Concord Hospital Tick-Borne Disease Diagnostic Algorithm



To the original PowerPlan™ a CBC w/diff as well as CMP was added. The algorithm was to be embedded within the PowerPlan™ and the option to initiate treatment targeting Lyme Disease, *Anaplasmosis*, or *Babesiosis*, with embedded internet links to current evidence-based guidelines was proposed.

During the PowerPoint™ provider education lunch and learn the algorithm and PowerPlan™ was presented with opportunity for questions to be answered after instruction on it's use. In the original proposal a six-week period was allotted for follow up analysis, however due to provider availability, time-constraints with the PowerPlan™ Cerner build team, two-weeks were given prior to release of the Qualtrix™ post-test which included short-answer free-text questions on effectiveness and utility of the algorithm and PowerPlan™. The PowerPlan™

changes were released, however the recorded presentation and algorithm was not released system wide within the timeframe of data analysis as originally had been specified in our proposal.

Study of the Interventions

Through utilizing the Qualtrix™ software and the pre-posttest model, we were able to study the impact of the PowerPoint™ educational lunch and learn model with regards to improvement in provider scores in the categories of identifying tick-borne disease symptoms, appropriate diagnostic selection, and treatment of the specific disease states. A 20% improvement in posttest scores was proposed to indicate increased provider knowledge of tick-borne diseases including *Anaplasmosis*, *Babesiosis*, and Lyme Disease. The three additional posttest questions assessed the impact of the Tick-Borne Disease PowerPlan™ and algorithm. The pre-post intervention query of the current PowerPlan™ assessed utilization of the new Tick-Borne Disease PowerPlan™.

Measures

Provider knowledge was measured via the pre and posttest which contained the same questions utilizing evidence-based material including clinical signs and symptoms of *Anaplasmosis*, *Babesiosis*, and Lyme Disease, as well as current clinical practice guidelines for treatment which healthcare providers should have a basis of knowledge around. Improvement was defined as provider improving their knowledge assessment score by 20%. The posttest also measured the effectiveness of the mode of educational delivery (i.e., face-face learning), and whether the improved Tick-Borne Disease PowerPlan™ and algorithm were useful tools over the month study period. The pre-post intervention chart audit and query of the current vs. updated

PowerPlan™ and algorithm measured utilization of the improved Tick-Borne Disease PowerPlan™ and algorithm.

Analysis

Pre-posttest categorical data regarding clinical signs, symptoms, and treatment of *Anaplasmosis*, *Babesiosis*, and Lyme Disease, was analyzed for percentage of questions correct. We proposed statistical analysis to be conducted using a two-sampled t-test or Wilcoxon signed rank-test to determine if there was a statistically significant improvement in knowledge at the two-week mark which came about because of the educational lunch and learn session.

Chart audit of the frequency of use of the current Tick-Borne Disease PowerPlan™ and the improved Tick-Borne Disease PowerPlan™ and algorithm was calculated. Again, a two-sampled t-test was proposed to determine statistical significance.

Ethical Considerations

Ethical considerations include possible conflict of interest as the author and DNP candidate is a member of the Infectious Disease Team and known to many colleagues which may pose response bias during the posttest period. That said, this DNP quality improvement work does not include vulnerable populations such as the patient. This proposal will be submitted to the University of New Hampshire Quality Committee to assess criteria for quality improvement work. This proposal will also be submitted to the Concord Hospital Human Investigations Committee for review.

Results

Evolution of the Intervention

Indeed, three Concord Hospital practices were identified within the catchment area spanning approximately 76 miles. In the proposal we had identified one of these practices within the heart of Concord, however due to provider availability and vacation schedules the internal medicine practice could not accommodate our timeframe and therefore a satellite outpatient primary care office to the North of Concord was selected. As proposed the three practices contained a mixture of provider types: NP, PA, MD/DO. A large stakeholder team had been identified and met on multiple occasions to make proposed changes to the Tick-Borne Disease PowerPlan™. Given time limitations and delays regarding approval of the plan changes within the Cerner build team only the CBC with differential and the CMP were added to the PowerPlan™. The algorithm was created, however again given time constraints and delays in approval the link was unable to be embedded within the PowerPlan™ at the time of provider educational sessions, therefore a separate paper handout was given to each provider who attended the session. Furthermore, the treatment links for *Anaplasmosis* and *Babesiosis* were not added prior to the presentation, although these options were slated to be updated on the next Cerner build team approval meeting. We had originally identified a time frame of three months, although due to time constraints as outlined above, a one-month project timeframe was identified from time of first PowerPlan™ change (CBC w/diff &CMP) to post-presentation and assessment analysis. Qualtrics™ provider knowledge assessment was sent via anonymous link prior to the lunch and learn presentation. A post-assessment was sent two-weeks after, which was a shorter timeframe than originally planned, again to obtain analysis prior to the end of March which was identified in our proposal. The query of the PowerPlan™ was performed after the presentations, and again somewhat limited with regards to gravity of the project due to time constraints and seasonality. In addition, there was an opportunity to present for the University of New England Doctor of Osteopathic Medicine student cohort at Concord Hospital Laconia. The students received the pre-presentation knowledge assessment as well as the post-presentation assessment. This was not part of the proposal, however, since these students are considered the future of medicine, and there is a growing epidemic of tick-borne disease, the results of their pre-post assessment were included in our data set.

Demographic Data

Demographic questions included a query of their profession, year in school for pre-licensure participants, years in practice post-licensure for providers, and their self-report of perceived knowledge. The majority of providers were nurse practitioners and all of the students were in their 3rd year. The majority of the providers have been in practice between 5-10 years and the perception prior to the educational presentation was of moderate knowledge.

There were thirteen total respondents in the pre-presentation knowledge assessment, six students, three nurse practitioners, two physician assistants, and two medical doctors (MD). There were eleven respondents who answered the post-assessment for comparison. In the post-test, again we saw three nurse practitioner responses, two physician assistants, but only one MD. The majority of respondents had been practicing 5-10 years, students excluded (Table 1). Eight out of the thirteen respondents (62%) perceived themselves as moderately knowledgeable regarding various tick-borne diseases from both the provider and student groups, whereas four out of the six students (31%) were slightly knowledgeable according to their self-perceptions, and one from the provider group indicated they were very knowledgeable (7%).

Table 1

General Demographics

General Characteristics	**Total Sample (N=13) *n* (%)**
Profession	
Nurse Practitioner	3 (23)
Physician Assistant	2 (15)
MD/DO	2 (15)
Student	6 (46)
Pre-Licensure Year in Medical School	**Total Sample (N=6) *n* (%)**
1st	0 (0)
2nd	0 (0)
3rd	6 (100)
4th	0 (0)
Post-Licensure Years in Practice	**Total Sample (N=7) *n* (%)**
0-4	1(14)
5-10	5 (72)
11-15	0 (0)
16-20	1 (14)
20 or Greater	0 (0)
How Knowledgeable are you with tick-borne disease?	**Total Sample (N=13) *n* (%)**
Not Knowledgeable at all	0(0)
Slightly Knowledgeable	4(31)
Moderately Knowledgeable	8(62)
Very Knowledgeable	1(7)
Extremely Knowledgeable	0(0)

Descriptive statistical analysis

Babesiosis Knowledge Pre-Licensure Participants. In looking at *Babesiosis* directed questions, there were a wide range of symptoms for possible selection, however in the pre-test, no one identified shortness of breath or cough to be a symptom, whereas 3 out of 5 (60%) of the students correctly identified this after the presentation. There was a 50% increase in overall pre-licensure knowledge with 5 out of 5 (100%) identifying nausea and vomiting as key findings on the post-test, and 4 out of 5 (80%) identifying urine abnormalities on the post-test when compared to the 2 out of 6 (33%) identifying this on the pre-test. When asked to identify CBC and CMP anomalies, in the pre-test 3 out of 6 (50%) identified thrombocytosis as a finding alongside anemia, with 4 out of 6 (67%) acknowledging this anomaly, when compared to 5 out of 5 (100%) correctly selecting these anomalies in the post-test. One-out of six students (17%) identified transaminitis & elevation in BUN within the pre-test, compared with 4 out of 5 (80%) in the post-test in these categories. No one had selected elevated creatinine pre-test, whereas 4 out of the 5 (80%) students correctly selected this in the post-test. On both the pre-presentation assessment and the post-presentation assessment 100% of the students identified the peripheral blood smear as a confirmatory test for acute *Babesiosis*. After the presentation, 4 out of 5 (80%) of the students correctly identified combination treatment of atovaquone and azithromycin as appropriate treatment for *Babesiosis*, compared to 3 out of 6 (50%) in the pre-test (Table 2).

Table 2

Pre-Licensure Babesiosis Knowledge

***Babesiosis* Symptoms**	**Pre-Test (N=6) *n* (%)**	**Post-Test (N=5) *n* (%)**
*Shortness of Breath & Cough	0 (0)	3 (60)
*Nausea & Vomiting	3 (50)	5 (100)
*Fever	6 (100)	4 (80)
*Night Sweats	4 (67)	4 (80)
*Headache	5 (83)	4 (80)
*Dark Urine	2 (33)	4 (80)
CBC & CMP Anomalies		
*Thrombocytopenia	3 (50)	5 (100)
*Transaminitis	1 (17)	4 (80)
*Anemia	4 (67)	5 (100)
*Leukopenia	1 (17)	3 (60)
*Elevated BUN	1 (17)	4 (80)
*Elevated Creatinine	0 (0)	4 (80)
Confirmatory Testing		
*Blood Parasite Smear	6 (100)	5 (100)
Antibody Testing	1 (17)	2 (40)
*PCR Testing	5 (83)	3 (60)
Blood Culture	0 (0)	0 (0)
***Babesiosis* Treatment**		
Doxycycline	2 (33)	1 (20)
Atovaquone	1 (17)	0 (0)
*Atovaquone + Azithromycin	3 (50)	4 (80)

*=Correct Responses

Babesiosis Knowledge Post-licensure Participants. Looking at the post-licensure providers, 1 out of 7 (14%) correctly identified shortness of breath or cough as a symptom in the pre-test whereas 3 out of 6 (50%) identified this correctly on the post-test. Nausea and vomiting were identified by all 6 providers to be a possible symptom on the post-test when compared to 6 out of 7 (86%) on the pre-test. Four out of six (67%) correctly identified abnormalities within the urine in the post-test when compared to three out of seven (43%) in the pre-test. Regarding anomalies within the CBC and CMP, each symptom saw an increase in awareness in the post test with renal abnormalities the most striking with 4 out of 6 (67%) correctly identifying this in the post-test when compared with only 1 out of 7 (14%) selecting elevation in BUN/Creatinine in the pretest. Five out of seven (71%) of the providers identified the peripheral smear as a confirmatory test on the pre-test, when compared to 6 out of 6 (100%) on the post-test. After the presentation, 5 out of the 6 (83%) providers accurately chose the combination treatment of atovaquone and azithromycin as gold standard for *Babesiosis* when compared to 5 out of 7 (71%) in the pre-test, the other two providers (29%) selecting Doxycycline (Table 3).

Table 3

Post-Licensure Babesiosis Knowledge

***Babesiosis* Symptoms**	**Pre-Test (N=7) *n* (%)**	**Post-Test (N=6) *n* (%)**
*Shortness of Breath & Cough	1 (14)	3 (50)
*Nausea & Vomiting	6 (86)	5 (83)
*Fever	7 (100)	6 (100)
*Night Sweats	6 (86)	6 (100)
*Headache	7 (100)	6 (100)
*Dark Urine	3 (43)	4 (67)
CBC & CMP Anomalies		
*Thrombocytopenia	5 (71)	6 (100)
*Transaminitis	4 (58)	4 (67)
*Anemia	4 (58)	6 (100)
*Leukopenia	4 (58)	5 (83)
*Elevated BUN	1 (14)	4 (67)
*Elevated Creatinine	1 (14)	4 (67)
Confirmatory Testing		
*Blood Parasite Smear	5 (71)	6 (100)
Antibody Testing	3 (43)	1 (17)
*PCR Testing	6 (86)	5 (83)
Blood Culture	0 (0)	0 (0)
***Babesiosis* Treatment**		
Doxycycline	2 (29)	1 (17)
Atovaquone	0 (0)	0 (0)
*Atovaquone + Azithromycin	5 (71)	5 (83)

*=Correct Responses

Anaplasmosis Knowledge Pre-licensure Participants. Turning our attention to signs and symptoms of acute *Anaplasmosis*, we saw an increase in awareness of the possibility of mental status changes 5 out of 5 (100%), nausea (100%), and 4 out of 5 (80%) selecting headache as presenting symptoms with *Anaplasmosis* when compared to 4 out of 6 (67%), 5 out of 6 (83%), and 4 out of 6 (67%) identifying these in the pre-test respectively. A case-scenario describing a patient presenting with a few of the symptoms was presented next, with a goal to identify labs which may be useful for such a patient. On both the pre-test and post-test 100% of the students correctly identified a CBC with differential and an acute tick-borne disease panel would be of use. There was a 50% increase in selecting Lyme antibodies and a 67% increase with peripheral blood smear selection from pre to post-test with 100% of the students identifying these tests as useful after the presentation. Similar to anomalies seen with acute *Babesiosis*, each anomaly listed for acute *Anaplasmosis* saw an increase in awareness with 5 out of 5 (100%) selecting thrombocytosis and anemia compared with 4 out of 6 (67%) and 3 out of 6 (50%) in the pre-test, and 4 of 5 (80%) selecting leukopenia and transaminitis in the post-test compared with 1 of 6 (17%) and 2 of 6 (33%) in the pre-test (Table 4). A true/false question was posed on incubation period for acute *Anaplasmosis*, with 4 of 5 students (80%) correctly acknowledging the false statement of six weeks on the post-test compared with the majority, 4 out of 6 (67%), believing six weeks to be the appropriate incubation period in the pre-test. All of the students selected doxycycline as the appropriate treatment of acute *Anaplasmosis* after the educational session when compared to 3 out of 6 (50%) in the pre-test period.

Table 4

Pre-Licensure Anaplasmosis Knowledge

***Anaplasmosis* Symptoms**	**Pre-Test (N=6) *n* (%)**	**Post-Test (N=5) *n* (%)**
*Fever	6 (100)	4 (80)
*Myalgia	6 (100)	4 (80)
*Fatigue	6 (100)	4 (80)
*Nausea & Vomiting	5 (83)	5 (100)
*Headache	4 (67)	4 (80)
*Arthralgia	6 (100)	3 (60)
*Mental Status Changes	4 (67)	5 (100)
CBC & CMP Anomalies		
*Thrombocytopenia	4 (67)	5 (100)
*Transaminitis	2 (33)	4 (80)
*Anemia	3 (50)	5 (100)
*Leukopenia	1 (17)	4 (80)
Laboratory Testing		
*CBC w/Diff	6 (100)	5 (100)
*CMP	5 (83)	3 (60)
*Acute Tick Panel	6 (100)	5 (100)
Lyme Abs	3 (50)	5 (100)
*Peripheral Blood Smear	4 (67)	5 (100)
Anaplasmosis Abs	2 (33)	2 (40)
Incubation Period >6 weeks		
True	4 (67)	1 (20)
*False	2 (33)	4 (80)
***Anaplasmosis* Treatment**		
*Doxycycline	3 (50)	5 (100)
Atovaquone + Azithromycin	5 (50)	0 (0)

*=Correct Responses

Anaplasmosis Knowledge Post-licensure Participants. All providers selected fatigue, nausea, headache, and mental status changes as symptoms of acute *Anaplasmosis* post-presentation when compared with 67% (fatigue, nausea, headache) and 71% (mental status changes) selecting these options on the pre-test respectively (Table 5). On both knowledge assessments, all providers correctly identified fever and myalgia as possible symptoms of acute anaplasmosis. Post-licensures were given the same clinical scenario as pre-licensures and asked to identify useful laboratory testing. Five-out of six providers (83%) correctly selected the peripheral blood smear when compared with 4 out of 7 (57%) on the pre-test, and 6 of 6 (100%) correctly selected CMP on post-test compared with 6 of 7 (86%) prior. On both the pre-and post-knowledge assessments they correctly identified that a CBC with differential and an acute tick-borne disease panel would be helpful diagnostic studies for this patient. Regarding findings within the CBC and CMP, the most significant increase in awareness of anemia as an anomaly of *Anaplasmosis* was noted with five out of six (83%) accurately selecting this compared with three out of seven (43%) on the pre-test. Leukopenia and thrombocytopenia were recognized by 100% of the providers as possible abnormalities of acute *Anaplasmosis* on the post-test when compared with 5 out of 7 (71%) identifying this prior. Despite the educational session, there was very minimal increase in providers identifying the correct the incubation period for *Anaplasmosis* of under six weeks, 58% pre-test compared to only 67% post-test. That said, 100% correctly identified doxycycline as the appropriate treatment of *Anaplasmosis* post-test compared with 86% prior to the lunch and learn.

Table 5

Post-Licensure Anaplasmosis Knowledge

***Anaplasmosis* Symptoms**	**Pre-Test (N=7) *n* (%)**	**Post-Test (N=6) *n* (%)**
*Fever	7 (100)	6 (100)
*Myalgia	7 (100)	6 (100)
*Fatigue	6 (86)	6 (100)
*Nausea & Vomiting	6 (86)	6 (100)
*Headache	6 (86)	6 (100)
*Arthralgia	4 (57)	5 (83)
*Mental Status Changes	5 (71)	6 (100)
CBC & CMP Anomalies		
*Thrombocytopenia	5 (71)	6 (100)
*Transaminitis	5 (71)	5 (83)
*Anemia	3 (43)	5 (83)
*Leukopenia	5 (71)	5 (83)
Laboratory Testing		
*CBC w/Diff	7 (100)	6 (100)
*CMP	6 (86)	6 (100)
*Acute Tick Panel	7 (100)	6 (100)
Lyme Abs	5 (71)	5 (83)
*Peripheral Blood Smear	4 (58)	5 (83)
Anaplasmosis Abs	1 (14)	1 (17)
Incubation Period >6 weeks		
True	3 (43)	2 (33)
*False	4 (57)	4 (67)
***Anaplasmosis* Treatment**		
*Doxycycline	6 (86)	6 (100)
Atovaquone + Azithromycin	1 (14)	0 (0)

*=Correct Responses

Ehrlichiosis & Lyme Disease Pre-licensure Participants. All respondents correctly identified doxycycline as appropriate treatment for *Ehrlichiosis*, *Ixodes scapularis* (Black legged tick) as the tick vector for *Anaplasmosis*, *Babesiosis*, and Lyme disease, and lastly all identified that Lyme disease was caused by *Borrelia burgdorferi* on both pre-and post-tests (Table 6). Another case scenario question was posed, this time a seven-year-old boy with a bullseye lesion and no allergies presented to the clinic. All six students (100%) correctly acknowledged that confirmatory testing was not needed prior to treating this patient on the pre-test, compared with 4 of 5 (80%) on the post-test. That said, all five (100%) correctly identified that the seven-year-old could receive doxycycline (the gold standard treatment) on the post-test compared with 5 of 6 (83%) advising doxycycline was preferred treatment prior to the presentation.

Table 6

Pre-Licensure Ehrlichiosis & Lyme Disease Knowledge

***Ehrlichiosis* Treatment**	**Pre-Test (N=6) *n* (%)**	**Post-Test (N=5) *n* (%)**
*Doxycycline	6 (100)	5 (100)
Bacteria Causing Lyme Disease		
**Borrelia Burgdorferi*	6 (100)	5 (100)
A 7-YO boy presents with a bullseye lesion & fatigue. You need to confirm Lyme disease with lab testing?		
True	0 (0)	1 (20)
*False	6 (100)	4 (80)
True or false, you treat the 7-YO with Doxycycline?		
*True	5 (83)	5 (100)
False	1 (17)	0 (0)

*=Correct Reponses

Ehrlichiosis & Lyme Disease Post-Licensure Participants. All providers correctly identified Lyme disease was caused by *Borrelia burgdorferi*, and acute *Ehrlichiosis* treatment consisted of doxycycline on both pre-and post-tests. On the pre-test 7 of 7 (100%) accurately identified *Ixodes scapularis* (Black legged tick) as the tick vector for *Anaplasmosis*, *Babesiosis*, and Lyme disease although on the post-test, one provider incorrectly selected *Dermacentor variabilis* (American dog tick). All 6 providers (100%) recognized that confirmatory testing was not needed prior to treatment of the seven-year-old boy with the bullseye lesion on the post-test compared with 6 out of 7 (86%) prior to the presentation. On both pre-post testing, 100% of the providers acknowledged that despite his age, doxycycline was the appropriate treatment.

Table 7

Post-Licensure Ehrlichiosis and Lyme Disease Knowledge

***Ehrlichiosis* Treatment**	**Pre-Test (N=6) *n* (%)**	**Post-Test (N=5) *n* (%)**
*Doxycycline	6 (100)	5 (100)
Bacteria Causing Lyme Disease		
**Borrelia Burgdorferi*	6 (100)	5 (100)
A 7-YO boy presents with a bullseye lesion & fatigue. You need to confirm Lyme disease with lab testing?		
True	0 (0)	1 (20)
*False	6 (100)	4 (80)
True or false, you treat the 7-YO with Doxycycline?		
*True	5 (83)	5 (100)
False	1 (17)	0 (0)

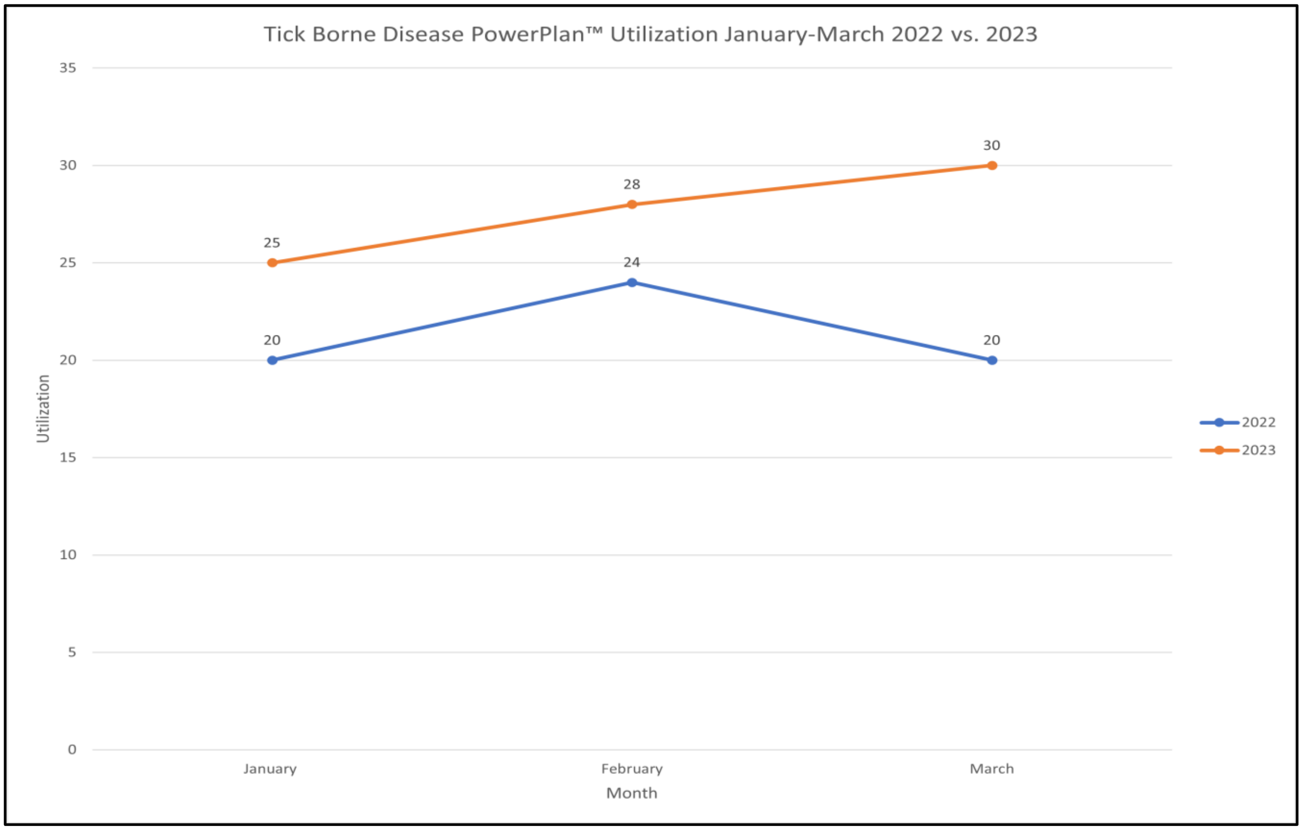
*=Correct Responses

PowerPlan™ Utilization

A data query of the PowerPlan™ from the Concord Hospital electronic medical record (EMR) was performed from 2022 and 2023, particularly the months of January, February, and March as this was the project timeframe. When compared with 2022 data, all three months saw increased access and utilization of the PowerPlan™ in 2023, with access increasing 1.5 times after the lunch and learn presentations in March (Figure 3). Of note, March data was partial as it was midway through the month when data was collected. All six of the providers (100%) and five of the students (100%) who took part in the post-test answered the free-text question about the perceived utility of the education for future practice.

Figure 3

Tick-Borne Disease PowerPlan™ Utilization January-March 2022 vs. 2023



Inferential Statistical Analysis

On both the pre-and post-assessments, respondents were asked to identify an anonymous four-digit number to aide in matched comparison. Out of the respondents only seven were able to be matched for comparison, three post-licensure providers and four pre-licensure students. We utilized SPSS software (IBM, 2017) to run the Wilcoxon signed rank-test to determine if there is a median difference to scores from an individual over time (Lund Research, LTD, 2013). Due to the small sample size both pre-licensure and post-licensure respondents were combined.

Table 8

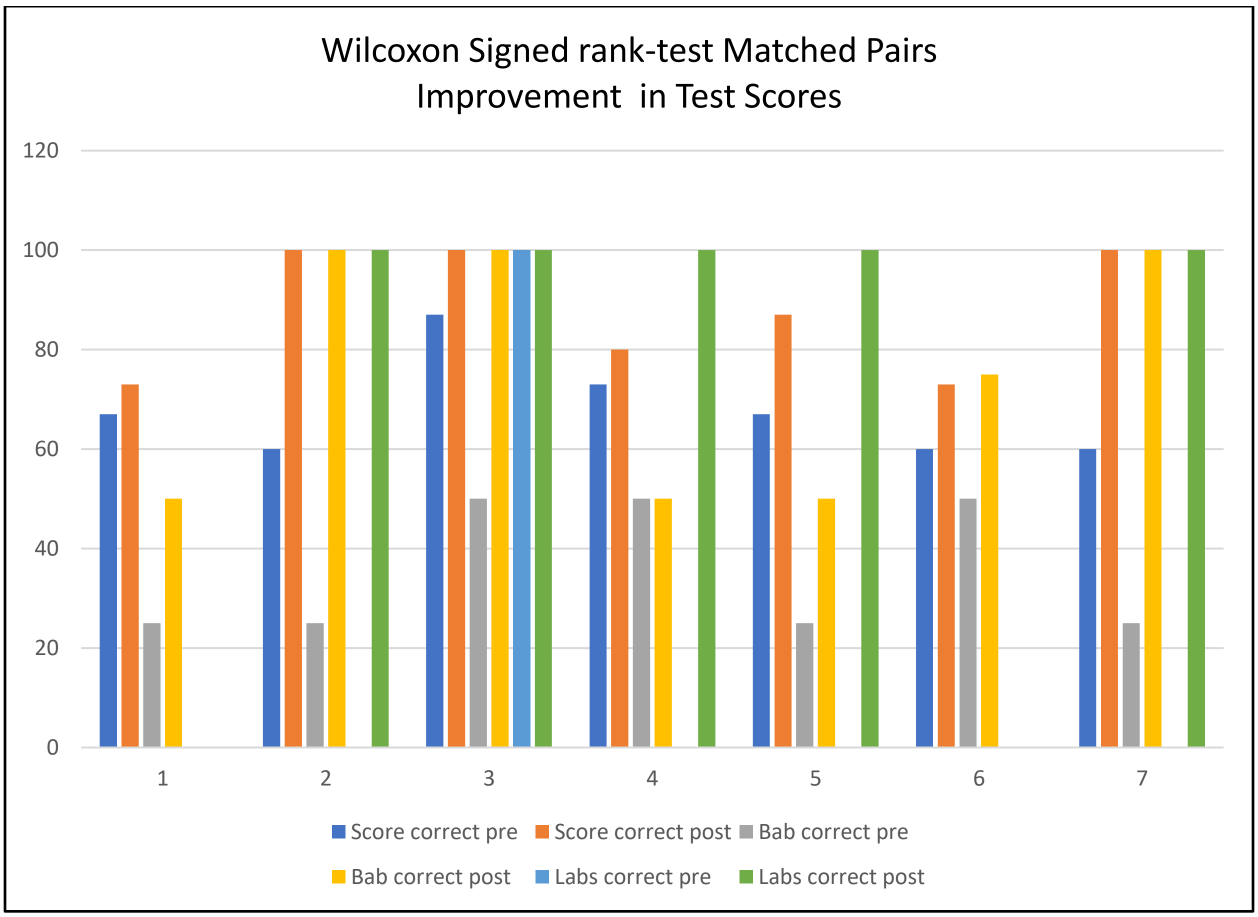
Wilcoxon Signed Rank Summary

Null Hypothesis	**Test**	***Z***	***P***
The median differences between Pre-test total score and Post-test total score equals 0.	Related samples Wilcoxon Signed Rank-Test	2.379	0.017
The median differences between Pre-test and Post-test laboratory knowledge equals 0.	Related samples Wilcoxon Signed Rank-Test	2.000	0.046
The median of differences between Pre-test and Post-test knowledge of *Babesiosis* equals 0.	Related samples Wilcoxon Signed Rank-Test	2.232	0.026
The median of differences between Pre-test and Post-test knowledge of *Anaplasmosis* equals 0.	Related samples Wilcoxon Signed Rank-Test	1.890	0.059
The median of differences between Pre-test and Post-test knowledge of *Ehrlichiosis* & Lyme Disease equals 0.	Related samples Wilcoxon Signed Rank-Test	.000	1.000

There was a statically significant change in overall test scores prior to the educational session when compared to after, z=2.379, p=0.017 (Figure 4). We additionally found a statistically significant change in respondents ordering correct laboratory studies when presented with a tick-borne disease case presentation, z= 2.0, p=0.046. Looking at specific disease states, there were no significant changes for *Ehrlichiosis* or Lyme as all respondents answered questions correctly on both pre and post-tests, however there was a statistically significant increase in knowledge of *Babesiosis*, z= 2.232, p=0.026. Where there was statistical significance in overall knowledge of *Babesiosis*, respondent knowledge improvement regarding *Anaplasmosis* was not of statistical significance, z=1.890, p=0.059.

Figure 9

Wilcoxon Signed Rank-Test Matched Pair Pre-Post Presentation Test Scores



Contextual Elements

It was proposed that both in-person lunch and learn presentations as well as a recorded option would be made available for providers. Three face-to-face presentations were given with one recorded presentation, although not made available system wide at the time of data collection due to IT delay. This was unintended and limited our overall reach within the Concord Hospital catchment. As above, we also anticipated performing statistical analysis using Wilcoxon signed rank-testing, asking respondents to identify an anonymous four-digit number for matched comparison on *all* data. Three out of the six providers who responded were able to be matched, compared to four out of the five students, therefore the Wilcoxon signed rank-testing was only able to be used for seven out of the eleven respondents. Given this paired with low response rate, we additionally used aggregate descriptive statistical analysis.

We had also anticipated all changes to the PowerPlan™ would be made prior to the educational sessions, however due to time restraints and lag in committee approval, only the CBC with differential, and CMP were added, leaving out the treatment recommendation links for *Anaplasmosis*, *Babesiosis*, and *Ehrlichiosis* which were proposed. An unexpected positive consequence was acknowledged after a provider was moved enough to send personal correspondence after one of the educational sessions.

Missing Data

Upon review of the data one provider provided consent, however, failed to answer any questions on the post-test therefore this provider was excluded from data analysis. This phenomenon took place in the student pre-test as well and therefore this student was excluded from data analysis. Another provider failed to answer three out of the fifteen questions therefore missed answers were scored as zero.

Discussion

Summary

The global aim of this work was to improve provider recognition of tick-borne illnesses in the outpatient setting to curb delays in treatment leading to hospitalization and sequala of disease progression. Our first specific aim was to increase provider awareness of symptoms as well as appropriate diagnostic testing associated with tick borne illness by 20%. Our second specific aim was to increase Tick-Borne Disease PowerPlan™ utilization by 40%. There were three key findings in this quality improvement project including difference between perceived and actual knowledge of tick-borne illnesses, knowledge deficits both at the pre-licensure and post-licensure level, and increased use of the PowerPlan™.

Difference in Perceived vs. Actual Knowledge of Tick-Borne Disease

As outlined extensively herein there is a growing concern with regards to the emerging threat of tick-borne diseases across North America, and in particular the Northeast. The practices selected were primary care practices seeing patients of all age ranges whom are apt to appear with presentations matching that of various tick-borne illnesses as described in the knowledge assessment. It is interesting that most of the providers reported perceived moderate understanding of various tick-borne diseases, with one reporting they were very knowledgeable, when the average test score prior to the presentation in the provider group was 68%. The majority of the student group identified themselves as slightly knowledgeable with only two reporting moderate knowledge, yet their combined score prior to the presentation was 58%.

There are incongruencies between provider assumption of knowledge and actual knowledge of clinical features of these diseases. While these incongruencies were also noted for the pre-licensure participants, the differences were not so profound.

Medical Education Knowledge

Despite the majority of provider respondents acknowledging 0-10 years in practice (i.e., graduating within the last ten years), knowledge deficits in identifying signs and symptoms, as well as appropriate laboratory testing and treatment modalities of various tick-borne diseases persist. Furthermore, medical school education around tick-borne diseases such as *Anaplasmosis* and *Babesiosis* may be insufficient even at the third-year mark, which was the targeted pre-licensure group.

A specific aim of this project included improving awareness of signs, symptoms, and laboratory testing for tick-borne illnesses by 20%. Where the target percentage was not met, we were able demonstrate a meaningful increase in both pre-licensure & post-licensure post-test scores as validated by Wilcoxon signed rank inferential statistical analysis (z=2.379, p=0.017) after the lunch and learn education. The average pre-test score in the provider group increased from 69% to 83%, and the students were able to improve their combined average score from 58% to 75%. The knowledge gained was most profound for *Babesiosis* (z= 2.232, p=0.026), and identifying clinically significant laboratory studies among tick-borne disease cases (z= 2.0, p=0.046).

PowerPlan™ Utilization

Despite delayed system wide roll out of the PowerPlan™ and algorithm and only collecting curtailed data in March, there was an uptick in utilization during the months of

January through March in 2023 when compared to 2022 (83 PowerPlan™ access points vs 64). Our specific aim outlined a 40% increase in utilization, however just under 30% increase was seen. The increase may have been in part due to a warmer than usual winter. While it was not planned, the local news channel, WMUR servicing New Hampshire, in conjunction with New Hampshire Department of Health and Human Services and the Centers for Disease Control featured a story regarding the rise in Babesiosis cases in New England (Ketschke, 2023), further emphasizing the relevance and timeliness of our PowerPlan™ and algorithm as tools for the front-line clinician.

Interpretation

Our first specific aim of this quality improvement project was to increase provider knowledge of tick-borne disease by 20%. We needed to establish baseline understanding and knowledge of various tick-borne diseases in a clinical setting and through a presentation with question-and-answer session, improve upon the knowledge base using a pre-post test design method. In conjunction with improving upon understanding of *Anaplasmosis*, *Babesiosis*, and *Ehrlichiosis*, our second specific aim was to increase PowerPlan™ utilization by 40%. To do this we reconstructed and enhanced the original Tick-Borne Disease PowerPlan™ with the development and implementation of a point-of-care algorithm for the clinician. As previously noted above given time constrictions the CBC with differential and the CMP were added to the PowerPlan™ during the time of data collection.

Despite not meeting a 20% increase in aggregate post-test scores as noted above, aggregate pre-post data does suggest that the educational intervention in the form of a PowerPoint™ presentation with question-and-answer session did correlate with increased post-test average among both the provider and student groups. The Wilcoxon signed rank-test also identified a significant change in scores among our combined matched pairs. Given the time constraints the post-test went out in a relatively short-time frame, therefore we cannot infer whether or not long-term retention was ascertained. The low response rate of respondents again impairs the interpretation of this project and would need to be replicated on a larger scale for research purposes to confirm significance.

Lastly, we did not meet our specific aim of 40% increase in PowerPlan™ utilization given time restraints as noted above, however we did see utilization rise in the winter months when comparing 2022 and 2023 data. The short-answer question and feedback also supported increased utilization of the PowerPlan™ despite the partial month data.

Patterns and Themes

In the post-test, there was one short answer questions and one multiple choice question pertaining to clinical practice moving forward, specifically “Have you included TBD in practice moving forward”, and “Did you find this presentation along with the PowerPlan™ and algorithm helpful diagnostic tools moving forward”. Four out of the five pre-licensure students indicated they were planning to include this in their clinical practice moving forward, and all six of the post-licensure providers indicated they are considering this in their differential diagnosis. The short answer responses indicated that they were including *Anaplasmosis* and *Babesiosis* versus Lyme disease alone more often, and furthermore, they were considering these differentials year-round. Each respondent also found the point-of-care algorithm and updates to the PowerPlan™ useful. The increased utilization of the PowerPlan™ in the month also supports this feedback, even despite the partial month data.

Comparison with Other Publications

Other studies have demonstrated similar themes with disparities in provider knowledge around tick-borne illnesses. In a study recently published in 2021, researchers collected data utilizing online survey questionnaires on baseline knowledge of Lyme disease and other tick-borne diseases of front-line providers (primary care, urgent care, emergency care) in a tick-endemic area (Mattoon, et al 2021). Following this, they held focus educational sessions addressing challenges and concerns raised from the baseline knowledge assessment and much like our findings, common themes arose. They too found low response rates and had difficulty in engaging a larger group, and as such utilized descriptive statistical analysis. For those who did participate in the survey and focus group, clinicians were apt to state they were moderately knowledgeable on various tick-borne diseases, however the majority of respondents had difficulty identifying correct treatment options in patients with *Anaplasmosis*, *Babesiosis*, and additionally were unsure of further workup for case presentations with negative Lyme disease testing (Mattoon, et al. 2021). Only two medical doctors took part in our pre-test, with only one completing the totality of the post-test. Mattoon and colleagues (2021) demonstrated similar patterns at their outpatient clinics with only three physicians completing the survey questionnaire out of eight. This brings into question the concept of test or performance anxiety, or self-doubt regarding lack of knowledge around tick-borne diseases and therefore led to lack of participation, or incompletion. Studies have identified cynicism, self-doubt, and reduced personal accomplishment as factors that influence behavior patterns and can lead to burnout (Voltmer et al., 2021). Within focus groups, clinicians identified delivery method of information pertaining to tick-borne diseases in the form of CME or online modules was insufficient, and there needed to be an effort made at delivering point-of-care resources for both clinicians and patients to help with information retention (Mattoon, et al. 2021). Where researchers identified this need for point-of-care resources, they did not create one, unlike our quality improvement project where we combined the educational session with the updated PowerPlan™ and point-of-care algorithm.

Impact of this Quality Improvement Project

Despite the limited reach in phase one, this presentation and intervention was delivered at an opportune time as the spring and warmer weather approaches New England. The impacts we made on the small pilot groups were noted in many ways, from respondent feedback to personal emails, to acknowledgement by upper management within the Concord Hospital system. One emergency room provider at Concord Hospital-Laconia had asked when the algorithm was going to be made available system wide. Much like the study from Mattoon and colleagues (2021), there is an eagerness to deliver not only timely, but updated resources to the frontline providers in an effort to improve diagnosis and treatment. With the updated PowerPlan™, point-of-care algorithm, and recorded educational session soon to be uploaded, positive impacts on patients within the Concord Hospital catchment are fast approaching.

We had anticipated increased utilization with the PowerPlan™ after the system wide implementation, although we found that by comparison, even without the system wide roll out (to include media announcements on the intra-web), there was increased utilization. Contextually our hospital system is relatively small and communication among providers is robust, therefore this could have led in part to this outcome. We had also anticipated a larger volume of respondents which was not observed which could have been in part due to February vacation schedules, as well as the lack of a pre-recorded educational session that providers could have viewed at their convenience. Many providers have become used to virtual options for not only education but also for patient visits since the COVID-19 pandemic. It is quite clear that the flexibility online options provide will continue to evolve and persist for years to come (Lockee, 2021). Therefore, with any quality improvement project such as this, virtual options must be made available.

Opportunity Costs

There were no direct costs or strategic trade-offs associated with the quality improvement project, however at one of the provider question and answer sessions a recommendation was made regarding substituting the automatic CBC with differential for the manual differential. The context and rationale behind this was to limit laboratory call back for the blood parasite smear if there was abnormal results on the CBC. A cost-injury was performed and in fact the manual CBC was $4 less than the automated, thus reducing overall patient cost. With that knowledge a short review of the literature was performed regarding variation in results. Variation in manual differential was shown to range from 5-10%, whereas automated variation was ~3% (Meintker et al, 2013; Simon & Simon, 2019). Even with variation, the potential reduction in unnecessary travel to the laboratory with a reflexed manual differential to pathology, coupled with slight cost reduction for the patient, is a key opportunity cost that will be discussed in the next phase of the project.

Limitations

Limitations within our quality improvement project included time constraints, which in turn impacted sample size and reach of the in-person lunch and learn presentations. The delays in approval of the PowerPlan™ changes shortened the window of opportunity to present to practices within the Concord Hospital catchment. As previously noted above, many practices had providers on February vacation as well which limited our sample size. Attempts were made to contact ten practice managers to arrange for presentations as well as participation in the Qualtrics survey. Four managers responded and only three were able to secure dedicated time for the presentation.

As previously noted, statistical analysis was limited in two distinct ways. The first was the small sample size and the second, where we did have matched pairs, there was a very small set of pairs to conclude statistical significance. Therefore, the project including data collection and statistical analysis should be repeated with a larger participant pool. It is quite possible that the respondents knew they were of small sample size and therefore odds of anonymity were lower, therefore they did not feel comfortable assigning themselves a number. When looking at the two groups however, the students were more apt to provide a number. Since these students are currently in school and not post-licensure, the fear of repercussions for incorrect responses and low-test scores was potentially reduced when compared to post-licensures, leading to an increase in matched pairs.

Utilizing the online survey tool for knowledge assessment was another area where limitations may have existed. Studies have identified older members of society sometimes struggle with familiarizing themselves with new technologies and adoption of digital tools (Vassilakopoulou, & Hustad., 2021). All but one of the respondents who answered our survey questions had less than ten years in practice and therefore it is possible that the younger population was more comfortable with the online tool, exposing digital immigrants and the digital divide. Studies have also demonstrated a correlation between physician age and technology adoption as it relates to health information technology (Westgate, 2020). This again highlights the potential limitation of our knowledge assessment method, and therefore smaller sample size than if the assessment was in a more traditional paper format.

The last presentation was recorded which was part of our original proposal, however this was not posted to the intra-web prior to data collection, again limiting our reach. We were able to successfully add the CBC with differential and CMP to the existing PowerPlan™, however limitations existed as the blood parasite smear was not added, nor were the options for *Anaplasmosis*, *Ehrlichiosis*, or *Babesiosis* treatment prior to the lunch and learn presentations. As such, paper handouts of the algorithm with instructions to access the IDSA clinical practice guidelines were provided.

Conclusions

The COVID-19 pandemic emerged onto center stage in 2020 and left many state health departments shifting focus and funds into pandemic response yet left lingering in the background was a growing epidemic on the ground. In the March 17, 2023, Centers for Disease Control and Prevention *Morbidity and Mortality Weekly report*, Vermont, Maine, New Hampshire, and Connecticut saw exponential trends in Babesiosis cases from 2011-2019, with 1,602%, 1,422%, 372%, and 338% increase in cases respectively (Swanson et al., 2023). Not only did local news channels in New England pick up this story, but national stations such as American Broadcast Company (ABC) reported these findings as well (Cuénant, 2023). Multiple factors are driving such a phenomenon including climate change which not only lengthens duration of tick season but also human behavioral trends, such as spending more time outdoors. The COVID-19 virus demonstrated increased transmissibility in highly populated cities, and as such, New Hampshire and other surrounding states found their seasonal residents were more apt to become permanent, again potentially influencing the rise in tick-borne disease cases reported. Implications for this substantial rise are felt not only in New England, but nationwide, as *Babesia* can also be transmitted via blood transfusion, which has been shown to have significantly worse outcomes than acquiring the disease from the tick bite alone (Swanson et al., 2023).

This DNP quality improvement project demonstrated statistically significant increased awareness of clinical features of *Babesiosis* as well as necessary laboratory studies needed to accurately diagnose and treat this emerging disease. Overall, we were able to demonstrate significant increase in overall knowledge of various tick-borne diseases with improvement in test scores, and we provided an updated and targeted PowerPlan™ and point-of-care algorithm for providers on the frontline, which is not only useful, but as outlined by various sources above, ***timely***.

Using small PDSA cycles, the next phase of this project will implement the changes to the PowerPlan™ including embedded links for treatment and the algorithm. Once these changes have been made, the system-wide roll-out will take place. Having electronic point-of-care tools is apt to be more sustainable than the printed algorithm we handed out in the first phase of our quality improvement work. As providers intend to continue to practice in our hospital system, they need to sustain and expand their knowledge regarding emerging diseases such as *Babesiosis*, *Anaplasmosis*, and *Ehrlichiosis*. Having targeted education and point-of-care tools such as the ones outlined in our work is one way to help these efforts.

At the beginning of our quality improvement project there was significant discussion with state health officials initially regarding data requests, however, there continues to be interest at the state level with regards to dissemination of this work, importantly the presentation and algorithm. This work could be easily implemented in other macrosystems within not only our state such as Dartmouth Hitchcock Medical Center, and Catholic Medical Center, but New England wide including Massachusetts General Hospital, Maine Medical Center, and Yale-New

Haven Hospital in Connecticut. Furthermore, there are implications for implementation into medical education, which was gleaned through not only incorporating the third-year medical students but based on years in practice for the post-licensure group. Our findings and implications echo that of Mattoon and colleagues (2021), where opportunities were noted to include more in-depth training, comprehensive algorithms, and trusted point-of-care resources to aide in accurate diagnosis and treatment of tick-borne diseases. Where our project was New England specific based on emerging epidemiologic data, the same format and algorithm could be created throughout the country based on local epidemiology, as ticks are naturally occurring in all of the United States with the exception of Alaska (CDC, 2022).

Where there were no sources of funding for this quality improvement project, it is quite clear that there are opportunities for future work not only at the microsystem level, but at the macrosystem and metasystem level including state and national, as made evident in the recent CDC MMWR report. With enhanced educational interventions utilizing emerging epidemiologic trends, accurate and trusted point-of-care algorithms, clinicians will be poised to accurately diagnose and treat complex tick-borne diseases at the first symptom, preventing the potential grim sequelae of a missed diagnosis.

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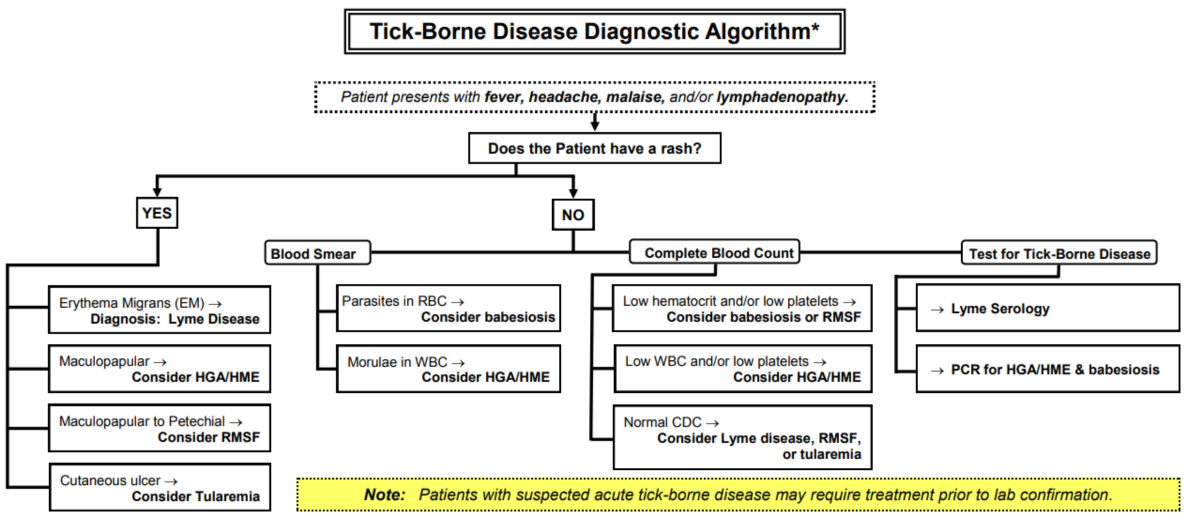
Appendix A

Dutchess County Tick-Borne Disease Algorithm



Courtesy of Dutchess County Department of Health - 85 Civic Center Plaza - Suite 106 - Poughkeepsie, New York 12601 (845) 486-3402 - Communicable Disease Control Division

This tool is intended to serve as a diagnostic framework for tick-borne disease, not to make a final diagnosis.
Additional information on diagnosis and treatment may be found online at www.cdc.gov/ticks

* Algorithm adopted from New York State Department of Health's Diagnosing Tick Borne Disease flyer, Massachusetts Department of Public Health Tick-borne Disease Physician's Reference Manual, and the Centers for Disease Control and Prevention's Tickborne Diseases of the United States: A Reference Manual for Health Care Providers.