VECTOR-BORNE DISEASES
Diagnostic Testing and Clinical Interpretation
**OUR VECTOR-BORNE DISEASE DIRECTORS**

**Bobbi Pritt, M.D.**
Dr. Bobbi Pritt is certified by the American Board of Pathology in clinical & anatomic pathology and microbiology. Her research interests include the evaluation and development of novel laboratory methods to aid in the diagnosis of parasitic and vector-borne diseases. Dr. Pritt works collaboratively with academic and public health partners to provide laboratory diagnostics and education in these areas to a global population. Some of her recent work resulted in the implementation of rapid and highly sensitive molecular tests for malaria, microsporidiosis, Lyme disease, and *Borrelia miyamotoi* infection. Dr. Pritt also played a key role in discovering and describing two new tick-borne pathogens: *Ehrlichia muris eauclairensis* and *Borrelia mayonii*. The latter bacterium causes Lyme disease in the upper Midwestern United States.

**Elitza Theel, Ph.D.**
Dr. Elitza Theel is certified by the American Board of Medical Microbiology. Her research interests include development and evaluation of novel methods for antibody and antigen detection as diagnostics, specifically for vector-borne and fungal diseases. Dr. Theel also spearheads an international laboratory outreach initiative in Belize. This initiative is focused on increasing the in-country diagnostic testing capacity for vector-borne diseases and on enhancing the current quality assurance/quality control practices in clinical laboratories throughout the country.

**OUR MICROBIOLOGY LABORATORY DIRECTORS**

**Bobbi Pritt, M.D.**
- Division Chair
- Parasitology
- Vector-borne diseases
- Infectious diseases anatomic pathology

**Matthew Binnicker, Ph.D.**
- Molecular virology
- Viral infections in transplant recipients
- Viral respiratory infections

**Robin Patel, M.D.**
- Biofilm-related infections
- Molecular bacteriology
- Sequencing-based bacteriology

**Andrew Norgan, M.D., Ph.D.**
- Clinical microbiology
- Infectious diseases anatomic pathology

**Nancy Wengenack, Ph.D.**
- Mycobacteriology
- Mycology
- Antimycobacterial and antifungal susceptibility testing

**Joseph Yao, M.D.**
- Hepatitis viruses
- Human immunodeficiency virus (HIV) infection
- Hepatitis and HIV antiviral susceptibility testing

**Jane J. Hata, Ph.D.**
- Laboratory Director, Florida
- Clinical microbiology

**Christopher P. Marquez, M.D.**
- Laboratory Director, Florida
- Clinical serology

**Thomas Grys, Ph.D.**
- Laboratory Director, Arizona
- Clinical microbiology

**Elitza Theel, Ph.D.**
- Infectious disease serology
- Vector-borne diseases
- Fungal diseases
THE RIGHT TESTS FOR
DETECTION AND DIAGNOSIS

Mayo Clinic’s internationally renowned clinical microbiology laboratories span all areas of conventional, molecular, and serological medical microbiology, offering a broad selection of tests designed for rapid identification and in-depth characterization of the pathogens associated with infectious diseases.

Mayo Clinic Laboratories offers a full menu of individual tests and panels that aid in the diagnosis of vector-borne diseases (VBD). In addition to our comprehensive testing menu, we developed multiple VBD testing algorithms to help guide and optimize diagnostic testing.

For more information about our VBD testing options and algorithms, visit mayocliniclabs.com/vectorborne.

Diagnostic testing for:

**Tick-Borne Diseases**
- Lyme Disease
- Babesiosis
- Anaplasmosis
- Ehrlichiosis
- Rocky Mountain Spotted Fever (RMSF)
- *Borrelia miyamotoi* Disease

**Mosquito-Borne Diseases**
- Malaria
- West Nile Virus
- Eastern Equine Virus
- Western Equine Virus
- California (La Crosse) Virus
- St. Louis Encephalitis Virus
- Chikungunya Virus
- Zika Virus
- Dengue Virus

**Other Vector-Borne Diseases**
- Visceral Leishmaniasis
- Parasite Identification (Arthropods)
- Chagas Disease
Tick-borne diseases (TBDs) occur worldwide, but historically, only certain pockets of the United States posed a risk for infection. However, the geographic range of ticks continues to expand in North America, leading to higher risks of TBD exposure for the public. As a result of increasing exposure and the rising number of potential tick-borne pathogens, it is increasingly important to recognize who to test, when to test, and what test to use for patients who present TBD symptoms.

We offer a full menu of individual tests and panels that aid in the diagnosis of TBDs. In addition to our comprehensive testing menu, we have developed multiple TBD testing algorithms to help guide and optimize diagnostic testing.
**Babesiosis**

**SYMPTOMS**
Flu-like symptoms, including fever, fatigue, malaise, and headache. Patients may have hepatomegaly and/or splenomegaly.

*In severe cases, hemolysis, acute respiratory distress syndrome, or shock may occur without prompt diagnosis and treatment.*

**PATHOGEN**
Protozoan parasites: Babesia microti, B. duncani, and B. divergens-like (MO-1 strain)

**VECTOR**
Ixodes ticks (black-legged ticks)—Babesia microti

**PRIMARY DISTRIBUTION**
United States – Northeast, Upper Midwest, and Pacific Coast regions
Canada

**Featured Testing**

- **BABG** | Babesia microti IgG Antibodies, Serum
- **LBAB** | Babesia Species, Molecular Detection, PCR, Blood
- **TICKS** | Tick-Borne Disease Antibodies Panel, Serum
- **EHBAP** | Ehrlichia/Babesia Antibody Panel, Immunofluorescence, Serum
- **TKPNL** | Tick-Borne Panel, Molecular Detection, PCR, Blood

**Anaplasmosis**

**SYMPTOMS**
Fever, headache, muscle pain, malaise, chills, nausea and abdominal pain, cough, and confusion.

*Due to the potential for severe symptoms and death, consider presumptive treatment while awaiting test results.*

**PATHOGEN**
Intracellular bacterium: Anaplasma phagocytophilum

**VECTOR**
Ixodes ticks

**PRIMARY DISTRIBUTION**
United States – Northeast, Mid-Atlantic, Northcentral, and Pacific Coast regions
Canada

**Ehrlichiosis**

**SYMPTOMS**
Flu-like symptoms, including fever, fatigue, malaise, myalgias/arthritis, and headache.

*Due to the potential for severe symptoms and death, consider presumptive treatment while awaiting test results.*

**PATHOGEN**
Rickettsiales bacteria: Ehrlichia chaffeensis, E. ewingii, and E. muris subsp. eauclairensis

**VECTOR**
Amblyomma ticks for E. chaffeensis and E. ewingii.
Ixodes scapularis for E. muris subsp. eauclairensis

**PRIMARY DISTRIBUTION**
United States – Southeast and Southcentral regions
Europe (less frequent)

**Featured Testing**

- **EHRCP** | Ehrlichia Antibody Panel, Serum
- **EHRL** | Ehrlichia/Anaplasma, Molecular Detection, PCR, Blood
- **EHRC** | Ehrlichia chaffeensis (HME) Antibody, IgG, Serum
- **TICKS** | Tick-Borne Disease Antibodies Panel, Serum
- **EHBAP** | Ehrlichia/Babesia Antibody Panel, Immunofluorescence, Serum
- **TKPNL** | Tick-Borne Panel, Molecular Detection, PCR, Blood

**Rocky Mountain Spotted Fever (RMSF)**

**SYMPTOMS**
High fever, chills, severe headache, muscle aches, nausea, vomiting, and fatigue.

*Due to the potential for severe symptoms and death, consider presumptive treatment while awaiting test results.*

**PATHOGEN**
Intracellular, coccobacillus bacteria: Spotted Fever Group Rickettsia (e.g., Rickettsia rickettsii)

**VECTOR**
Dermacentor and Rhipicephalus ticks

**PRIMARY DISTRIBUTION**
United States – Northeast region
Canada
Central America

**Featured Testing**

- **SFGP** | Spotted Fever Group Antibody, IgG and IgM, Serum
- **TICKS** | Tick-Borne Disease Antibodies Panel, Serum
- **EHBAP** | Ehrlichia/Babesia Antibody Panel, Immunofluorescence, Serum
- **TKPNL** | Tick-Borne Panel, Molecular Detection, PCR, Blood

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**Borrelia miyamotoi Disease**

**SYMPTOMS**
High fever, headache, myalgias, fatigue, and arthralgias. Note that symptoms—specifically fever—may occur in a biphasic manner.

**PATHOGEN**
Spirochete bacterium: Borrelia miyamotoi

**VECTOR**
Ixodes ticks

**DISTRIBUTION**
North America
Europe
Japan

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**FEATURED TESTING**

- **BMIYB** | Borrelia miyamotoi Detection PCR, Blood
- **BMIYC** | Borrelia miyamotoi Detection PCR, Spinal Fluid
- **TKPNL** | Tick-Borne Panel, Molecular Detection, PCR, Blood

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**Tick-Borne Coinfections Testing Options**

Tick-borne pathogen coinfections are more widespread than commonly recognized by medical professionals and the public. Ticks can transmit multiple infectious agents through a single bite to the host. In studies reported in *Clinical Microbiology* reviews, coinfections appear with the greatest frequency among people with Lyme disease (LD). Approximately 4–5% of patients with LD are coinfected with either human anaplasmosis or babesiosis where LD is endemic.6

Mayo Clinic, a recognized center of excellence for vector-borne diseases, offers combined expertise with consultancy, integration of serologic and molecular testing, and enhanced reports with interpretation support.

**Serological Testing**
A tick-borne testing panel can assist in the detection of coinfections, even if they are not initially suspected by the provider. Such tests can evaluate patients who present with fever, myalgia, headache, nausea and other symptoms and have a history or suspicion of tick exposure. Importantly, this testing is useful in patients presenting with more than seven days of symptoms.

**Molecular Testing**
While two-tiered serological testing best identifies Lyme disease caused by *B. burgdorferi*, molecular amplification assays are the best detectors for acute ehrlichiosis, anaplasmosis, babesiosis, and *B. miyamotoi* infections within the first 7 days following symptom onset. This tick-borne panel offers sensitive, specific, and rapid detection of agents that cause these four diseases. Consider ordering this panel when systemic symptoms, such as fever, chills, and sepsis, are present.

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**COMPREHENSIVE PANEL**

**TICKS** | Tick-Borne Disease Antibodies Panel, Serum

**INCLUDED TESTS**

- **EHRC** | *Ehrlichia chaffeensis* (HME) Antibody, IgG, Serum
- **ANAP** | Anaplasma phagocytophilum (Human Granulocytic Ehrlichiosis) Antibody, Serum
- **BABG** | Babesia microti IgG Antibodies, Serum
- **LYME** | Lyme Disease Serology, Serum
- **REFLEX TEST (IF INDICATED)**
  - **LYWB** | Lyme Disease Antibody, Immunoblot, Serum

**ADJUNCT PANEL**

- **EHBAP** | Ehrlichia/Babesia Antibody Panel, Immunofluorescence, Serum

**COMPREHENSIVE PANEL**

**TKPNL** | Tick-Borne Panel, Molecular Detection, PCR, Blood

**INCLUDED TESTS**

- **LBAB** | Babesia Species, Molecular Detection, PCR, Blood
- **EHRL** | *Ehrlichia/Anaplasma*, Molecular Detection, PCR, Blood
- **BMIYB** | *Borrelia miyamotoi* Detection, PCR, Blood
MOSQUITO-BORNE DISEASES

Worldwide, mosquito-borne diseases (MBDs) cause millions of deaths each year, earning mosquitoes the title of the world’s deadliest animal.5

We offer a comprehensive menu of individually orderable tests and panels for MBDs. Additionally, our algorithmic approaches to MBD testing help reduce costs and optimize patient care.

Malaria

SYMPTOMS
Fever, headache, chills, nausea, vomiting, muscle pain, fatigue, sweating, chest or abdominal pain, and cough.

If not treated within 24 hours, malaria can lead to death from one or more serious complications,7 including:
- Cerebral malaria
- Breathing problems
- Organ failure
- Anemia
- Low blood sugar

PATHOGEN
Protozoan parasite:
Plasmodium species
- P. falciparum
- P. vivax
- P. ovale
- P. malariae
- P. knowlesi

VECTOR
Anopheles mosquitoes

DISTRIBUTION
Sub-Saharan African
Southeast Asia
Eastern Mediterranean (less frequent)
Western Pacific
South America
North America (less frequent)
- Dominican Republic
- Haiti
Oceania
- Papua New Guinea

FEATURED TESTING

LCMAL Malaria, Molecular Detection, PCR Only
LMALP Malaria PCR with Parasitemia Reflex
MAL Rapid Malaria/Babesia Smear
West Nile Virus

SYMPTOMS
Mild infection: Fever, headache, body aches, vomiting, diarrhea, fatigue, and skin rash.

Neurological infection: High fever, severe headache, stiff neck, disorientation or confusion, stupor or coma, tremors or muscle jerking, seizures, partial paralysis, or muscle weakness.

If neurological symptoms are left untreated, patients may develop encephalitis or meningitis. Approximately 1 out of 10 people who develop severe central nervous system (CNS) illnesses die.1,4

PATHOGEN
Positive-stranded ribonucleic acid (RNA) virus: Flavivirus genus, Flaviviridae family

VECTOR
Primarily Culex mosquitoes

DISTRIBUTION
Africa
Europe
Middle East
West Asia
Oceania
North America (less frequent)

FEATURED TESTING
- WNS | West Nile Virus Antibody, IgG and IgM, Serum
- WNC | West Nile Virus Antibody, IgG and IgM, Spinal Fluid
- LCWNV | West Nile Virus, Molecular Detection, PCR, Spinal Fluid
- WNVP | West Nile Virus, Molecular Detection, PCR, Plasma

PCR tests are recommended to be used in conjunction with serological tests.

Eastern Equine Encephalitis Virus

SYMPTOMS
Systemic infection: Chills, fever, malaise, arthralgia, and myalgia.

Encephalitic infection: Fever, headache, irritability, restlessness, drowsiness, anorexia, vomiting, diarrhea, cyanosis, convulsions, and coma.

PATHOGEN
Arbovirus: Alphavirus genus, Togaviridae family

VECTOR
Culiseta mosquitoes

DISTRIBUTION
North America
Central America
South America
Caribbean

FEATURED TESTING
- EEEP | Eastern Equine Encephalitis Antibody, IgG and IgM, Serum
- EEPC | Eastern Equine Encephalitis Antibody Panel, IgG and IgM, Spinal Fluid

FEATURED PANELS
- ARBOP | Arbovirus Antibody Panel, IgG and IgM, Serum
- ABOPC | Arbovirus Antibody Panel, IgG and IgM, Spinal Fluid
**Western Equine Encephalitis Virus**

**SYMPTOMS**
Malaise, fever, headache, nausea, vomiting, vertigo, photophobia, sore throat, respiratory symptoms, abdominal pain, and myalgia.

**PATHOGEN**
Arbovirus: Alphavirus genus, Togaviridae family

**VECTOR**
Culex, Culiseta, and Aedes mosquitoes

**DISTRIBUTION**
- North America: Western Canada, Western United States
- South America: Argentina

**FEATURED TESTING**
- WEEP | Western Equine Encephalitis Antibody, IgG and IgM, Serum
- WEPCP | Western Equine Encephalitis Antibody Panel, IgG and IgM, Spinal Fluid

**California (La Crosse) Encephalitis**

**SYMPTOMS**
Fever, headache, nausea, vomiting, fatigue, and lethargy. More severe symptoms, including seizures, coma, and paralysis, often lead to encephalitis.

**PATHOGEN**
Serogroup virus: Bunyavirus genus, Bunyaviridae family

**VECTOR**
Aedes and Culex mosquitoes

**DISTRIBUTION**
- United States – Midwestern, Mid-Atlantic, and Southeast regions
- South America

**FEATURED TESTING**
- CAVP | California Virus (La Crosse) IgG and IgM, Serum
- CAVPCP | California Virus (La Crosse) Encephalitis Antibody Panel, IgG and IgM, Spinal Fluid

**St. Louis Encephalitis Virus**

**SYMPTOMS**
- Mild infections: Fever, headache, dizziness, nausea, and malaise.
- CNS infections: Stiff neck, confusion, disorientation, dizziness, tremors, and unsteadiness.

**PATHOGEN**
Positive-stranded ribonucleic acid (RNA) virus: Flavivirus genus, Flaviviridae family

**VECTOR**
Culex mosquitoes

**DISTRIBUTION**
- United States – Eastern, central, and rural western regions

**FEATURED TESTING**
- STLP | St. Louis Encephalitis Antibody, IgG and IgM, Serum
- STLPCP | St. Louis Encephalitis Antibody Panel, IgG and IgM, Spinal Fluid

**Chikungunya Virus**

**SYMPTOMS**
- Fever, joint pain, fatigue, muscle pain, headache, and rash.

**PATHOGEN**
Single positive-stranded RNA alphavirus: Alphavirus genus, Togaviridae family

**VECTOR**
Aedes mosquitoes

**DISTRIBUTION**
- Africa
- Asia
- Europe
- Islands in the Caribbean, Indian, and Pacific Oceans

**FEATURED TESTING**
- CHIKV | Chikungunya IgM and IgG, Antibody, Serum
- CHIKSP | Chikungunya Virus, PCR, Molecular Detection, Serum
- CHIKCP | Chikungunya Virus, PCR, Molecular Detection, Spinal Fluid
Zika Virus

**SYMPTOMS**
Mild fever, rash, joint or muscle pain, headache, and conjunctivitis. The Zika virus may cause other neurological disorders such as Guillain-Barre syndrome.

**Birth defects:**
Severe microcephaly with a partly collapsed skull, brain damage, reduced brain size, eye damage, joint problems—including limited motion—and reduced body movement caused by too much muscle tone after birth.

**PATHOGEN**
Single-stranded RNA virus: Flavivirus genus, Flaviviridae family

**VECTOR**
Aedes aegypti and Aedes albopictus mosquitoes

**DISTRIBUTION**
Africa
Southeast Asia
South America
Central America

**FEATURED TESTING**

<table>
<thead>
<tr>
<th>Test Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>MZIKV</td>
<td>Zika Virus IgG Antibody Capture MAC-ELISA, Serum</td>
</tr>
<tr>
<td>RZIKU</td>
<td>Zika Virus, PCR, Molecular Detection, Random, Urine</td>
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<tr>
<td>RZIKS</td>
<td>Zika Virus, Virus, PCR, Molecular Detection, Serum</td>
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<tr>
<td>PNZIK</td>
<td>Prenatal Zika Virus IgM Antibody Capture MAC-ELISA, Serum</td>
</tr>
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**Dengue Virus**

**SYMPTOMS**
Mild infection:
High fever, headache, muscle, bone and joint pain, nausea, vomiting, pain behind the eyes, swollen glands, and rash.

Dengue hemorrhagic fever, severe dengue, or dengue shock syndrome:
Severe abdominal pain, persistent vomiting, bleeding from gums or nose, bleeding under the skin (which might look like bruising), difficult or rapid breathing, cold or clammy skin (shock), fatigue, irritability, and restlessness.

**Symptoms of dengue hemorrhagic fever, severe dengue, or dengue shock syndrome signal life-threatening emergencies.**

**PATHOGEN**
Single positive-stranded RNA virus: Flavivirus genus, Flaviviridae family

**VECTOR**
Aedes aegypti and Aedes albopictus mosquitoes

**DISTRIBUTION**
North America
South America
Central America
Africa
Eastern Mediterranean
Southeast Asia
Western Pacific

**FEATURED TESTING**

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<tr>
<th>Test Code</th>
<th>Description</th>
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<tr>
<td>DENG M</td>
<td>Dengue Virus Antibody, IgG and IgM, Serum</td>
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<tr>
<td>DEN VP</td>
<td>Dengue Virus Antibody/Antigen Panel, Serum</td>
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<td>DFS AG</td>
<td>Dengue Virus NS1 Antigen, Serum</td>
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<td>DENG C</td>
<td>Dengue Virus, Molecular Detection, PCR, CSF</td>
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<td>DENG S</td>
<td>Dengue Virus, Molecular Detection, PCR, Serum</td>
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**FEATURED PANELS**

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<tr>
<th>Panel Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>ARBOP</td>
<td>Arbovirus Antibody Panel, IgG and IgM, Serum</td>
</tr>
<tr>
<td>ABO PC</td>
<td>Arbovirus Antibody Panel, IgG and IgM, Spinal Fluid</td>
</tr>
</tbody>
</table>
INSECT-BORNE DISEASES

Our laboratories test for various diseases carried by insect species. The tsetse fly spreads sleeping sickness, which affects 36 countries of sub-Saharan Africa and places 55 million people at risk. Sand flies spread the leishmaniasis group of diseases, which affects 88 countries and places 350 million people at risk. Household bugs spread Chagas disease and place 100 million people at risk in Latin America. Other insects spread filarial diseases, including lymphatic filariasis, loiasis, and onchoceriasis.

Pictured above: Phlebotomus papatasi sand fly

Visceral Leishmaniasis

SYMPTOMS
- Cutaneous leishmaniasis: One or more sores on the skin, papules (bumps), nodules (lumps), ulcers with crust or scabs, and swollen glands near the sores. Patients may also be asymptomatic.
- Visceral leishmaniasis: Fever, weight loss, enlargement of the spleen and liver, and abnormal blood tests with anemia, leukopenia, or thrombocytopenia.

PATHOGEN
- Parasite: Leishmania genus

VECTOR
- Female phlebotomine sand flies

DISTRIBUTION
- Asia
- Middle East
- Africa – tropical and northern regions
- Southern Europe
- Mexico
- Central America
- South America

FEATURED TESTING

LEIS | Leishmaniasis (Visceral) Antibody, Serum

Test is NOT appropriate for diagnosing cutaneous leishmaniasis.
Parasite Identification (Arthropods)

**SYMPTOMS**
Arthropods serve as disease vectors and cause disease by tissue damage and blood loss.

**VECTOR**
- Ticks
- Fleas
- Mites
- Lice
- Reduviid bugs

**DISTRIBUTION**
Varies with arthropod

**FEATURED TESTING**
- PARID | Parasite Identification, Varies

**Trypanosoma cruzi Infection (Chagas Disease)**

**SYMPTOMS**

**Acute phase:** Often asymptomatic. Mild signs include swelling at the infection site, fever, fatigue, rash, body aches, eyelid swelling, headache, loss of appetite, nausea, diarrhea, vomiting, swollen glands, and enlargement of the liver or spleen.

**Chronic phase:** Irregular heartbeat, congestive heart failure, sudden cardiac arrest, difficulty swallowing due to enlarged esophagus, abdominal pain, and constipation due to enlarged colon.

*If left untreated, the infection persists and advances to the chronic phase. Symptoms may occur 10–20 years after initial infection and may be life threatening.*

**PATHOGEN**
Protozoan hemoflagellate:
*Trypanosoma cruzi*

**VECTOR**
Reduviid (“kissing bugs”) Triatoma

**DISTRIBUTION**
- Rural regions of Mexico
- Central America
- South America

**FEATURED TESTING**
- CHAG | Trypanosoma cruzi IgG Antibody ELISA, Serum

*Test is preferred for diagnosis of chronic Chagas disease.*
THE MAYO CLINIC DIFFERENCE

Our clinicians and laboratorians focus on maintaining high-quality, cost-effective, and efficient care by using algorithmic, evidence-based approaches that lead to correct diagnoses and treatment, while minimizing unnecessary testing.

More importantly, physicians and scientists manage our laboratories with expert knowledge regarding the clinical implications of each test result and how it impacts patient care.

For more information about our vector-borne disease testing and algorithms, visit mayocliniclabs.com/vectorborne.

REFERENCES