Exhaustive Systematic Review: Rickettsiosis in Mexico: Diversity, Distribution and Epidemiology of Reemergence

by Ana Karem Ramírez-Utrera*

*Unidad de investigación médica de Enfermedades infecciosas y parasitarias, Centro Médico Nacional SXXI, IMSS. CDMX. México.

Corresponding author: Ana Karem Ramírez Utrera

Unidad de investigación médica de Enfermedades infecciosas y parasitarias, unidad médica de alta especialidad pediatría, Centro Médico Nacional SXXI, IMSS. Av. Cuauhtemoc 330, CP: 06720,

Alcaldía Cuauhtemoc, Mexico city. Mexico. Phone (52) 2282445664.

E- mail: karemramirezut@gmail.com

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ABSTRACT

Objective: To consolidate and compile current knowledge on Rickettsiosis in Mexico.

Materials and Methods: An exhaustive literature search was conducted in specialized databases up to September 2025. The systematic review resulted in the inclusion of 72 published articles**.**

Results: Fourteen species of Rickettsia were recorded in Mexico. These species are grouped into four main phylogenetic groups: Basal Group (BG), Typhus Group (TG), Transitional Group (TRG), and Spotted Fever Group (SFG). Rickettsiae have been associated with 26 arthropod species (14 hard ticks, 3 soft ticks, 2 lice, and 7 fleas) and 17 mammal species. Rickettsia prowazekii (Agent of Epidemic Typhus): Recorded in 21 Mexican states, making it the species with the widest distribution. Reported vertebrate hosts include Homo sapiens, and it has been detected in vectors such as Pediculus humanus humanus. Rickettsia typhi (Murine Typhus Agent): Recorded in 18 states. Hosts include rodents (Mus musculus and Rattus rattus) and vectors such as the cat flea (Ctenocephalides felis felis). Rickettsia rickettsii (RMSF Agent): Recorded in 12 states. Limited Distribution Species: Species detected in only one state include Rickettsia bellii, Rickettsia lusitaniae, Rickettsia rhipicephali, and Candidatus Rickettsia andeanae.

Discussion: This work represents an effort to consolidate the dispersed knowledge on rickettsiosis in Mexico. The reemergence and persistence of rickettsiosis with high lethality underscores the urgent need for a "One Health" strategy that integrates social, veterinary, and medical actions. The methodological challenge of distinguishing Rickettsia rickettsii from less pathogenic SFG species using generic PCR is significant and requires the strict adoption of advanced molecular taxonomic protocols. Research must advance the accurate characterization of these pathogens to effectively guide public health policies and mitigate the risk of these emerging and re-emerging diseases in Mexico.

Keywords: Rickettsiosis, tick-borne disease, Rocky Mountain spotted fever.

1. Introduction.

Rickettsiae are prokaryotic microorganisms of the family Rickettsiaceae, order Rickettsiales. They are obligate intracellular bacteria transmitted by arthropod vectors and cause diseases of medical and veterinary importance, including emerging and re-emerging diseases worldwide (1).

Since the isolation of the first member of the genus Rickettsia in 1906, named Rickettsia rickettsii, from a human patient in Montana, USA, at least 15 species have been recognized as relevant pathogens of medical and veterinary importance. These are transmitted by various hematophagous arthropods, such as ticks, fleas, and lice, to diverse species of terrestrial vertebrates, including humans (2). The genus Rickettsia comprises 35 valid species of intracellular coccobacilli bacteria capable of infecting various eukaryotic taxa (2).

In Mexico, 14 species of Rickettsia have been described, which have been associated with 26 species of arthropods (14 hard ticks, 3 soft ticks, 2 sucking lice, and 7 fleas) and 17 species of mammals distributed across 30 Mexican states (2). Ticks (Acari: Ixodida) are the main transmission vector described in Mexico. They are obligate hematophagous mites that parasitize all classes of vertebrates, from birds and reptiles to mammals, including humans, and have a worldwide distribution, serving as key vectors for a wide variety of bacterial, viral, and parasitic pathogens (3,4).

These arthropods can acquire the infection through four different routes: 1) horizontal transmission, when an uninfected arthropod feeds on a vertebrate infected with active bacteremia; 2) transovarial maintenance, in which the pathogen is transmitted from the female to her offspring during embryogenesis; And finally, 3) co-feeding transmission, which occurs when the pathogen is transmitted between vectors that feed in close proximity to one another on the same host at the same time, potentially infecting each other even if the host does not present with bacteremia. (2)

Despite the high relevance of these bacteria as pathogens (5), the role of Rickettsia as a component of biodiversity in Mexico is a field of study about which little is known. This is mainly due to the fact that most available studies are geographically dispersed, and some of the oldest reports, published at the beginning of the 20th century, are in local bulletins or journals that are difficult to access, and also due to the scarcity of research conducted in our country on human patients (5,6).

This systematic review's primary objective is to consolidate and expand current knowledge on members of the genus Rickettsia in Mexico and update their taxonomy to 2020. It sought to establish host-parasite relationships and determine the precise geographic distribution of each Rickettsia species present in the country (5). Furthermore, it integrated crucial information on other tick-borne pathogens and addresses the challenges of the reemergence of Rocky Mountain Spotted Rickettsiosis (RMSF) in Mexico, as well as its taxonomic and diagnostic implications at the molecular level.

2. Review Objectives

1. Inventory and Taxonomy: To gather and summarize the information available up to September 2025 on Rickettsia species present in Mexico, their geographic distribution, hosts, and vectors, and to perform the first phylogenetic reconstruction analysis of the available sequences of Mexican rickettsiae.

2. Epidemiology of Rickettsiosis: To evaluate the epidemiology of rickettsiosis, including the characterization of outbreaks and the identification of key risk factors and vectors, throughout Mexico.

3. Vectors of Rickettsiosis: To analyze the potential distribution of Ixodes scapularis, the competent vector in the transboundary region between Texas and Mexico and the rest of Mexican territory, and to report tick-borne infections in that area. 4. Diagnostic Standardization: Discuss the need for strict molecular standards for species identification within the genus Rickettsia, including the classic Fournier criteria and whole-genome sequencing (WGS) proposals, to overcome the limitations of generic detection methods.

3. Materials and Methods

3.1. Search Strategy and Inclusion Criteria

A comprehensive literature search was conducted in specialized databases such as Web of Science, Biological Sciences, Cochrane Library, BioOne, Google Scholar, Medline, PubMed, and Scopus up to September 2025.

Keywords: A combination of Spanish and English terms was used, including ‘Rickettsia’, ‘Mexico’, ‘Rickettsiosis’, ‘Tick-borne diseases’, ‘Typhus’, ‘Spotted fever’, ‘Tick-borne pathogens’, ‘Emerging diseases’, and ‘Vector-borne diseases’.

Inclusion Criteria: References without language restrictions were included, provided they strictly met two specifications:

1. Geographic and Host: Studies on arthropods and mammals (including human cases) that occur and were sampled or detected within Mexico and in the rest of the world.

2. Methodological: Identification of Rickettsia species (at least to the genus level) through the implementation of a presumptive/confirmatory serological or molecular test.

Exclusions: Thirteen references were excluded for not providing a serological or molecular technique for Rickettsia identification. Additionally, studies involving experimental infections were excluded. All studies eligible for descriptive analysis were retained, including case reports, case series, reviews, cross-sectional studies, cohort studies, and prevalence studies.

3.2. Data Extraction and Taxonomic Analysis

For each included study, the following data were meticulously recorded: (I) Rickettsia species, (II) detection method (e.g., isolation, molecular biology, serology), (III) accession numbers and molecular sequences deposited in GenBank (if available), (IV) disease caused, (V) complete taxonomic classification of the arthropod or mammalian host, (VI) number of positive animals per species, (VII) year of collection, and (VIII) locality (longitude and latitude).

To ensure taxonomic accuracy in the compilation, tick names were updated following Guglielmone et al. (2010), and mammal names following Wilson and Reeder (2005) and Ramírez-Pulido et al. (2014).

3.3. Molecular Phylogenetic Analysis

The first phylogenetic reconstruction was performed using Mexican Rickettsia sequences available in GenBank (5,19). Seventy-one sequences from four different genes were retrieved: gltA (citrate synthase, 20 sequences), htrA (18 sequences), ompB (17 sequences), and ompA (16 sequences) (19).

Global alignments were performed for each gene using the ClustalW algorithm in MEGA 6.0 (18). The optimal nucleotide substitution model was selected based on the lowest corrected Akaike Information Criterion (AICc). Subsequently, a Maximum Likelihood (ML) phylogenetic tree was generated for each gene using 10,000 bootstrap replicates.

The specific models used for tree reconstruction were:

• gltA (384 bp): Three-parameter Tamura model (T93) with Gamma (+G) distribution.

• htrA (434 bp): Three-parameter Tamura model (T93) with invariant sites (+I).

• ompA (486 bp): General Time Reversible (GTR) model with Gamma distribution (+G).

• ompB (765 bp): General Time Reversible (GTR) model with Gamma distribution (+G) and invariant sites (+I).

3.4. Methods for Characterizing Specific Pathogens

• RMSF in Mexicali: Clinical and epidemiological data from all RMSF cases reported to ISESALUD in the Mexicali metropolitan area and the Mexicali Valley during the period 2009–2019 were analyzed. The definition of a probable case used by the National Directorate of Epidemiology (DGE) is: any person of any age who presents with fever (>38.5°C) and ≥2 signs or symptoms (e.g., headache, myalgia, rash, etc.) plus ≥1 epidemiological criterion (e.g., history of tick bite or contact with an infested dog) in the two weeks prior to the onset of illness. Molecular diagnosis of PCR-confirmed cases was performed using assays specific to the genus Rickettsia.

• Modeling of Ixodes scapularis: To predict the potential distribution of I. scapularis in the Mexico-U.S. border region, unique presence locations were compiled from the literature and fieldwork. Environmental variables were used to build the model (MaxEnt), and it was evaluated using the Receiver Operating Characteristics (ROC) curve, calculating the Area Under the Curve (AUC).

4. Results

4.1. Literature Review and Historical Efforts

The systematic review resulted in the inclusion of 72 articles published up to the search deadline (September 2025). 44% of the articles were published in English and 36% in Spanish. Rickettsial research in Mexico has shown two historical peaks in production:

1. First Period (1930s and 1940s): 21 studies were published, mainly focused on the first three reported Rickettsia species.

2. Second Period (2000s onward): This is the most productive period, with 47 published studies, and it continues to the present.

4.2. Biological Diversity and Geographic Distribution of Rickettsia

A total of 14 Rickettsia species (including Candidatus species) have been recorded in Mexico. These species are grouped into four main phylogenetic groups: Basal Group (BG), Typhus Group (TG), Transitional Group (TRG), and Spotted Fever Group (SFG). Rickettsiae have been associated with 26 arthropod species (14 hard ticks, 3 soft ticks, 2 lice, and 7 fleas) and 17 mammal species.

Rickettsia Species with the Widest Geographic Distribution:

1. Rickettsia prowazekii (Agent of Epidemic Typhus): Recorded in 21 Mexican states, making it the species with the widest distribution. Reported vertebrate hosts include Homo sapiens, and it has been detected in vectors such as Pediculus humanus humanus.

2. Rickettsia typhi (Murine Typhus Agent): Recorded in 18 states. Hosts include rodents (Mus musculus and Rattus rattus) and vectors such as the cat flea (Ctenocephalides felis felis).

3. Rickettsia rickettsii (RMSF Agent): Recorded in 12 states, including Sonora, Baja California, Sinaloa, and Yucatán.

Species with Limited Distribution: Species detected in only one state include Rickettsia bellii, Rickettsia lusitaniae, Rickettsia rhipicephali, and Candidatus Rickettsia andeanae. For example, R. lusitaniae was associated with soft ticks (Ornithodoros yumatensis and Ornithodoros sp.) in Yucatán.

SFG of Clinical and Veterinary Relevance:

• R. rickettsii: Its reported vectors are diverse, highlighting the role of Rhipicephalus sanguineus s.l., as well as Amblyomma americanum, A. maculatum, A. mixtum (reinstated name), A. parvum, Dermacentor nitens and D. variabilis.

• R. parkeri: Detected in ticks Dermacentor parumapertus and R. sanguineus s.l. in six states. In South America, a strain of this bacteria, R. parkeri strain Atlantic Rainforest, causes human rickettsiosis of lower virulence, with bedsores, and has been detected in Amblyomma ovale ticks in Colombia.

• R. massiliae: Found in Rhipicephalus sanguineus s.l. in Baja California and Chihuahua.

4.3. Epidemiology of Rhino-San Francisco (RSF) in the Border Region (2009–2019)

RSF is a highly lethal infectious disease. The reemergence of RSF in Sonora and Baja California in the early 21st century is strongly linked to the presence of large populations of stray dogs infested with the brown dog tick (R. sanguineus s.l.) in impoverished neighborhoods.

Mexicali Outbreak: Analysis of cases in the metropolitan area and the Mexicali Valley (2009–2019) showed that the epidemic has persisted, with a high number of probable and confirmed cases.

• Diagnosis: Although the molecular assay used for case confirmation in Mexicali is specific to the genus Rickettsia, the extreme severity and consistent epidemiological and environmental evidence implicating R. sanguineus s.l. as the main vector strongly suggest that most PCR-confirmed cases were R. rickettsii infections.

• Case Fatality Rate and Risk Factors: Historically, case fatality rates have been very high (e.g., 80% in the Sinaloa and Sonora outbreaks between 1918 and 1943). Family-borne rickettsiosis (FRBD) has been characterized by affecting family groups, with children and women being particularly susceptible in some studies.

4.4. Detection of Rickettsia and Vector Distribution (Ixodes and Amblyomma)

4.4.1. Rickettsiosis in the Northeast

Modeling the distribution of Ixodes scapularis, the main vector of Rickettsiosis in the U.S., in the Texas-Mexico border region suggests a continuous suitable habitat extending into northern Mexico (Tamaulipas, Nuevo León, Coahuila).

• Vector Infection: Of the 661 ticks collected in Mexico, only 35 were identified as I. scapularis. Of these, 12 were infected with Borrelia burgdorferi. The infected ticks were found predominantly in four rural locations in the San Josesito district of Nuevo León, and one location in Tampico, Tamaulipas.

• Environmental Factors: The environmental factors that most contributed to the distribution pattern of I. scapularis were isothermal activity (20.0%), precipitation during the wettest quarter (18.1%), and the maximum temperature of the warmest month (14.6%). These factors confirm the close relationship of the species with temperature and humidity.

4.4.2. Richness of Hard Ticks in Mexico

The recent taxonomic update of the genera Ixodes and Amblyomma in Mexico (based on publications from 2007 to April 2023) shows high richness:

• Genus Ixodes: A total of 28 species are distributed. They are primarily associated with mammals (15 families) and birds (7 families). The most frequently parasitized mammal families are Cricetidae (15%), Canidae, and Procyonidae.

• Genus Amblyomma: 25 species are distributed. These species parasitize 13 families of amphibians and reptiles, seven of birds, and 21 of mammals. A. mixtum and Amblyomma dissimile were reported with the highest number of hosts.

• Taxonomic Challenges: The complexity of resolving taxonomic identity remains for species such as Ixodes affinis, whose populations in Mexico/Belize are molecularly distinct from those in South America. The presence of other species such as Ixodes cookei and Ixodes scapularis in Neotropical regions of Mexico is considered provisional or requires confirmation with fresh material.

5. Discussion and Analytical Synthesis

5.1. Methodological Challenges in Rickettsial Detection and Classification

The great biological diversity of rickettsiae in Mexico (14 species) significantly complicates clinical diagnosis and epidemiological surveillance. The coexistence of pathogenic species (R. rickettsii) with less virulent (R. parkeri) or non-pathogenic species requires species-level identification, which is often not achieved with generic molecular methods.

5.1.1. Limitations of PCR Based on Conserved Genes

Initial molecular detection of Rickettsia is frequently based on genes such as citrate synthase (gltA) or the 17 kDa protein. However, the gltA gene is highly conserved within the genus, which can result in the amplification of conserved regions from related species, hindering the accurate differentiation between R. rickettsii and other species of the SFG, such as R. parkeri.

This explains the occurrence of unusual Rickettsia–host/vector associations reported in Mexico, such as the detection of R. rickettsii in Amblyomma maculatum. These atypical detections likely represent the amplification of a nonspecific SFG pathogen or a typing error.

5.1.2. Taxonomic Standardization and the Need for Advanced Sequencing

It is essential that the sequences of Mexican rickettsiae be deposited in GenBank to facilitate local and regional systematic and epidemiological analyses. For taxonomic identification, it is imperative to use genotyping methods that accurately discriminate between species.

• Fournier Criteria (MLST): The classic, internationally recognized Fournier proposal requires the sequencing of at least five genes (16S rRNA, gltA, ompA, ompB, and the D gene) for the accurate classification of new rickettsiae. The nucleotide similarity thresholds required to classify an isolate as an approved species are strict: at least 99.8% for rrs (16S rRNA) and 99.9% for gltA.

• WGS Criteria: The most sensitive and accurate approach for classification is the phased implementation of whole-genome sequencing (WGS). This method uses dDDH thresholds > 92.3% and/or OrthoANI > 99.19 for species demarcation, allowing for more robust classification than MLST methods. Next-generation sequencing (NGS) has proven useful for the diagnosis of rickettsial diseases.

5.2. Clinical and Strategic Implications of Reemergence

The RMSF epidemic in northern Mexico, with its high case fatality rates, reflects a serious public health problem exacerbated by socio-environmental factors.

• Surveillance and Detection: In the clinical setting, molecular detection of SFGR is more sensitive in skin biopsy samples (37.5%) than in blood (3.9%). PCR of an eschar biopsy (tache noire) can be useful for detecting SFGR Rickettsiae and can be performed as early as 24 hours after a tick bite.

• One Health Approach: Outbreaks of rifampicin-related fecal infestations (RRF) are persistent and deadly, linked to the interaction between dogs, ticks (R. sanguineus s.l.), and the human environment in vulnerable communities. To mitigate the epidemiological risk, it is crucial to implement an integrated strategy that addresses social, environmental, veterinary, and medical factors. Inaction has severe economic and human consequences, with estimated costs exceeding US$13 million for similar outbreaks in the US, likely underestimating the true costs, especially those of long-term rehabilitation.

• Cellular Invasion: Pathogenesis studies have revealed that pathogenic and non-pathogenic rickettsiae (R. typhi, R. rickettsii, and R. montanensis) utilize bacterial phosphatidylserine (PS) to bind to the pherocytic receptor CD300f on macrophages (MΦ), facilitating their invasion and colonization. Macrophages are the first defense cells that rickettsiae encounter at the inoculation site and are key mediators for the elimination or dissemination of the pathogen.

5.3. Risk of Lyme Borreliosis in the Mexican Context

The detection of B. burgdorferi infecting I. scapularis in northeastern Mexico confirms the existence of a risk of Lyme borreliosis in the transboundary region. The distribution pattern of I. scapularis suggests a continuous ecological corridor influenced by climatic factors (temperature and precipitation).

The taxonomic classification of vectors should continue, especially in the genera Ixodes and Amblyomma, due to difficulties in morphological identification and the need to re-examine the type material of several species with atypical or uncertain distributions (e.g., I. cookei, I. scapularis in Oaxaca). The high tick richness (28 species of Ixodes and 25 of Amblyomma), and the diversity of associated hosts (amphibians, reptiles, birds, and 21 mammal families for Amblyomma), demonstrate the ecological complexity of zoonotic cycles in Mexico, requiring ongoing study to achieve a full understanding of their classification, distribution, and phylogenetic relationships.

6. Conclusion

This work represents an effort to consolidate the dispersed knowledge on rickettsiosis in Mexico. The biological inventory is substantial, with 14 Rickettsia species in key tick vectors in the border region. The reemergence and persistence of rickettsial fever in the north, with high lethality, underscores the urgent need for a "One Health" strategy that integrates social, veterinary, and medical actions.

The methodological challenge of distinguishing Rickettsia rickettsii from less pathogenic SFG species using generic PCR is significant and requires the strict adoption of advanced molecular taxonomic protocols (Fournier and WGS criteria). Research must advance the accurate characterization of these pathogens to effectively guide public health policies and mitigate the risk of these emerging and re-emerging diseases in Mexico.

You can consult:

1.Blanda V, Torina A, La Russa F, D'Agostino R, Randazzo K, Scimeca S, et al. A retrospective study of the characterization of Rickettsia species in ticks collected from humans. Ticks Tick-borne Dis. 2017;8:610–4.

2.Sánchez-Montes S, Colunga-Salas P, Lozano-Sardaneta YN, Zazueta-Islas HM, Ballados-González GG, Salceda-Sánchez B, et al. Emerging pathogens: Biodiversity and distribution of Rickettsia spp. in Mexico. Ticks Tick-borne Dis. 2021;12(1):101633.

3.Cortes-González M, Gámez-Moreno R. Tifus epidémico en Nuevo León: presentación del primer caso clínico pediátrico. Rev Enfer Infec Pediatr. 2008;22:56–9.

4.Álvarez-Hernández G, Contreras-Soto JJ. Letalidad por fiebre manchada por Rickettsia rickettsii en pacientes de un hospital pediátrico del estado de Sonora, 2004-2012. Salud Publ Méx. 2013;55:151–2.

5.Delgado de la Mora J, Licona-Enríquez JD, Leyva-Gastélum M, Delgado-De la Mora D, Rascón-Alcantar A, Álvarez-Hernández G. Una serie de casos fatales de fiebre manchada de las Montañas Rococsas en Sonora, México. Biomédica. 2018;38:69-76.

6.Braga-Ordóñez J, Balmaceda L, Pérez-Osorio L, Peniche-Lara G. Garrapatas (Ixodidae), potenciales transmisores de Rickettsia rickettsii en un municipio con alta frecuencia de infección por rickettsiosis. Ciencia y Humanismo en la Salud. 2016;3:56–60.

7.Bustamante ME, Varela G. Una nueva rickettsiosis en México existencia de la fiebre manchada Americana en los estados de Sinaloa y Sonora. Rev Inst Salubr Enferm Trop. 1943;4:189–210.

8.Bustamante ME, Varela G. Características de la fiebre manchada de las Montañas Rocosas en Sonora y Sinaloa, méxico (estudio de 12 casos y dos cepas). Rev Inst Salubr Enferm Trop. 1944;5:129–36.

9.Bustamante ME, Varela G. Estudios de fiebre manchada en México papel del Rhipicephalus sanguineus en la transmisión de la fiebre manchada en la República Mexicana. Rev Inst Salubr Enferm Trop. 1947;8:139–41.

10.Bustamante ME, Varela G, Otriz-Mariotte C. Estudios de fiebre manchada en México: La fiebre manchada en la Laguna. Rev Inst Salubr Enferm Trop. 1946;7:39–49.

11.Castillo-Martínez A. Detección de Rickettsia rickettsii Brump (Rickettsiales: rickettsiaceae) en la garrapata café del perro Rhipicephalus sanguineus Latreille (Ixodida: ixodidae) en la Comarca Lagunera, zona reemergente de fiebre manchada en México. Acta Zool Mex. 2017;33:339–44.

12.Castillo-Martínez A, Cueto-Medina SM, Hernández-Rodríguez S, Gallegos-Robles MA, Valdés-Perezgasga MT, Sánchez-Ramos FJ, et al. Detección de Rickettsia sp. En la garrapata café del perro Rhipicephalus sanguineus (Acari: ixodidae) en Matamoros, Coahuila, México. Acta Zool Mex. 2015;31:80–3.

13.Cuitun-Borges M, Castellanos-Escalante P, Carrillo-González N, Aguayo-Romero M, Balmaceda L. Presencia de Rickettsia sp en garrapatas Rhipicephalus sanguineus parasitando perros domésticos en la isla de Cozumel, Quintana roo, México. Ciencia Humanismo Salud. 2015;2:89–93.

14.Foley J, Tinoco-García L, Rodriguez-Lomelí M, Estrada-Guzmán J, Fierro M, Mattar-López E, et al. Unbiased assessment of abundance of Rhipicephalus sanguineus sensu lato ticks, canine exposure to spotted fever group Rickettsia, and risk factors in Mexicali, méxico. Am J Trop Med Hyg. 2019;101:22–32.

15.Fournier PE, Dumler JS, Greub G, Zhang J, Wu Y, Raoult D. Gene sequence-based criteria for identification of new rickettsia isolates and description of Rickettsia heilongjiangensis sp nov. J Clin Microbiol. 2003;41:5456–65.

16.Guzmán-Cornejo C, Sánchez-Montes S, Caso A, Rendón-Franco E, Muñoz-García CI. Molecular detection of Rickettsia rickettsii in ticks associated with the bobcat (Lynx rufus) in northeast Mexico. Ticks Tick-Borne Dis. 2019;10:1105–8.

17.Herrick KL, Pena SA, Yaglom HD, Layton BJ, Moors A, Loftis AD, et al. Rickettsia parkeri rickettsiosis, Arizona, USA. Emerg Infect Dis. 2016;22:780–5.

18.León AP. El concepto unicista de la etiología del tifo exantemático y la clasificación de la Rickettsia prowazeki. Rev Inst Salubr Enferm Trop. 1944;5:137–52.

19.López-Perez AM, Sánchez-Montes S, Foley J, Guzmán-Cornejo C, Colunga-Salas P, Pascoe E, et al. Molecular evidence of Borrelia burgdorferi sensu stricto and Rickettsia massiliae in ticks collected from a domestic-wild carnivore interface in Chihuahua, Mexico. Ticks Tick-Borne Dis. 2019;10:1118–23.

20.Lugo-Caballero C, Dzul-Rosado K, Rodríguez-Moreno G, Tello-Martín R, López-Ávila K, Zavala-Castro J. Caso fulminante de rickettsiosis (Rickettsia rickettsii) en una lactante del sureste de México. Arch Argent Pediatr. 2015;115:5–8.

21.Mariotte CO, Bustamante ME, Varela G. Hallazgo del Rhipicephalus sanguineus Latreille infectado naturalmente con fiebre manchada de las Montañas Rocosas en Sonora (méxico). Rev Inst Salubr Enferm Trop. 1944;5:297–300.

22.Martínez-Ortiz D, Torres-Castro M, Koyoc-Cardeña E, López K, Panti-May A, Rodríguez-Vivas I, et al. Detección molecular de Rickettsia typhi en roedores y pulgas en una comunidad rural de Yucatán, México. Rev Inst Med Trop Sao Paulo. 2016;58:1–4.

23.Merino O, De la Cruz NI, Martínez J, Pérez-de León AA, Romero-Salas D, Esteve-Gassent MD, et al. Molecular detection of Rickettsia species in ticks collected in the Mexico-USA transboundary region. Exp Appl Acarol. 2020;80:559–67.

24.Mooser H, Ruiz-Castañeda M, Zinsser H. Rats as carriers of Mexican typhus fever. JAMA. 1931;97:231–2.

25.Peniche-Lara G, Dzul-Rosado K, Pérez-Osorio C, Zavala-Castro J. Rickettsia typhi in rodents and R. felis in fleas in Yucatán as a possible causal agent of undefined febrile cases. Rev Inst Med Trop Sao Paulo. 2015;57:129–32.

26.Peniche-Lara G, Jimenez-Delgadillo B, Dzul-Rosado K. Rickettsia rickettsii and Rickettsia felis infection in Rhipicephalus sanguineus ticks and Ctenocephalides felis fleas co-existing in a small city in Yucatan, Mexico. J Vector Ecol. 2015;40:422–4.

27.Pieracci EG, Pérez-de la Rosa JD, Luna-Rubio D, Solis-Perales ME, Velasco-Contreras M, Drexler NA, et al. Seroprevalence of spotted fever group rickettsiae in canines along the United States-Mexico border. Zoonoses Public Health. 2019;66:918–26.

28.Sosa-Gutiérrez CG, Vargas-Sandoval M, Torres J, Gordillo-Pérez G. Tick-borne rickettsial pathogens in questing ticks, removed from humans and animals in Mexico. J Vet Sci. 2016;17:353–60.

29.Tinoco-Gracia L, Quiroz-Romero H, Quintero-Martínez MT, Rentería-Evangelista TB, Barreras-Serrano A, Hori-Oshima S, et al. Prevalence and risk factors for Borrelia burgdorferi infection in Mexicali, Baja California, a Mexico-US border city. Int J Appl Res Vet Med. 2008;6:161–5.

30.Sánchez-Montes S, Guzmán-Cornejo C, Martínez-Nájera Y, Becker I, Venzal J, Labruna M. Rickettsia lusitaniae associated with Ornithodoros yumatensis (Acari:Argasidae) from two caves in Yucatan, Mexico. Ticks Tick-Borne Dis. 2016;7:1097–101.

31.Sánchez-Montes S, Ríos-Muñoz CA, Espinosa-Martínez DV, Guzmán-Cornejo C, Berzunza-Cruz M, Becker I. First report of “Candidatus Rickettsia amblyommii” in west coast of Mexico. Ticks Tick-Borne Dis. 2016;7:1139–45.

32.Sánchez-Montes S, Isaak-Delgado AB, Guzmán-Cornejo C, Rendón-Franco E, Muños-García CI, Bermúdez S, et al. Rickettsia species in ticks that parasitize amphibians and reptiles: novel report from Mexico and review of the worldwide record. Ticks Tick-Borne Dis. 2019;10:987–94.

33.Sánchez-Montes S, Cabrera-Garrido MY, Ríos-Muñoz CA, Lira-Olguin AZ, Acosta-Gutiérrez R, Mata-Galindo M, et al. Detection of Bartonella and Rickettsia in small mammals and their ectoparasites in México. THERYA. 2019;10:69–79.

34.Sánchez-Montes S, Fernández-Figueroa EA, Gónzalez-Guzmán S, Paredes-Cervantes V, Ballados-Gonzales GG, Rangel-Escareño C, et al. New records of Haemaphysalis leporispalustris in the Transmexican Volcanic Belt province of Mexico with detection of rickettsial infection. Parasitol Res. 2020;119:1969–73.

35.Sánchez-Montes S, Salceda-Sánchez B, Ballados-González GG, Valtierra-Alzaga L, Soto-Gutiérrez JJ, Becker I. Rickettsia asembonensis: new records associated with the cat flea (Ctenocephalides felis felis) in Mexico. Vet Parasitol Reg Stud Reports. 2020;21:100418.

36.Zavala-Castro JE, Zavala-Velázquez J, Walker DH, Pérez-Osorio J, Peniche-Lara G. Severe human infection with Rickettsia felis associated with hepatitis in Yucatán, Mexico. Int J Med Microbiol. 2009;299:529–33.

37.Zavala-Velázquez JE, Ruiz-Sosa JA, Vado-Solis I, Billings AN, Walker DH. Serologic study of the prevalence of Rickettsiosis in Yucatán: evidence for a prevalent spotted Fever group Rickettsiosis. Am J Trop Med Hyg. 1999;61:405–8.

38.Zavala-Velázquez JE, Ruiz-Sosa JA, Sánchez-Elias RA, Becerra-Carmona G, Walker DH. Rickettsia felis rickettsiosis in Yucatán. Lancet. 2000;356:1079–80.

39.Zavala-Velázquez JE, Zavala-Castro JE, Vado-Solís I, Ruiz-Soza JA, Moron CG, Bouyer DH, et al. Identification of Ctenocephalides felis fleas as host of Rickettsia felis, the agent of a Spotted Fever Rickettsiosis in Yucatán, Mexico. Vector Borne Zoonotic Dis. 2002;2:69–74.

40.Jensen BB, Bruun MT, Jensen PM, Pedersen AK, Fournier PE, Skarphedinsson S, et al. Evaluation of factors influencing tick bites and tick-borne infections: a longitudinal study. Parasit Vectors. 2021;14:289.

41.Álvarez-Hernández G, Murillo-Benitez C, Candia-Plata MC, Moro M. Clinical profile and predictors of fatal Rocky Mountain spotted fever in children from Sonora, Mexico. Pediatr Infect Dis J. 2015;34:125–30.

42.Álvarez-Hernández G, González Roldán JF, Hernández Milan NS, Lash RR, Behravesh CB, Paddock CD. Rocky Mountain spotted fever in Mexico: past, present, and future. Lancet Infect Dis. 2017;17:e189–96.

43.Zazueta OE, Armstrong PA, Márquez-Elguea A, Hernández Milán NSH, Peterson AE, Ovalle-Marroquín DF, et al. Rocky Mountain Spotted Fever in a Large Metropolitan Center, Mexico–United States Border, 2009–2019. Emerg Infect Dis. 2023;29:292–300.

44.Guzmán-Cornejo C, Herrera-Mares A, Paredes-León R, García-Prieto L. Actualización de la riqueza de garrapatas de los géneros Ixodes y Amblyomma (Ixodida: Ixodidae) en México. Dugesiana. 2023;30:163-76.

45.Feria-Arroyo TP, Castro-Arellano I, Gordillo-Pérez G, Cavazos AL, Vargas-Sandoval M, Grover A, et al. Implications of climate change on the distribution of the tick vector Ixodes scapularis and risk for Lyme disease in the Texas-Mexico transboundary region. Parasit Vectors. 2014;7:199.

46.Gordillo-Pérez G, Vargas M, Solórzano-Santos F, Rivera A, Polaco OJ, Alvarado L, et al. Demonstration of Borrelia burgdorferi sensu stricto infection in ticks from the northeast of Mexico. Clin Microbiol Infect. 2009;15:496–8.

47.López-Castillo DC, Vaquera-Aparicio D, González-Soto MA, Martínez-Ramírez R, Rodríguez-Muñoz L, Solórzano-Santos F. Fiebre manchada de montañas rocosas: experiencia en 5 años de vigilancia activa en un hospital pediátrico de segundo nivel en el noreste de México. Bol Med Hosp Infant Mex. 2018;75:303–8.

48.Álvarez-Hernández G, Drexler N, Paddock CD, Licona-Enriquez JD, la Mora JD, Straily A, et al. Community-based prevention of epidemic Rocky Mountain spotted fever among minority populations in Sonora, Mexico, using a One Health approach. Trans R Soc Trop Med Hyg. 2020;114:293–300.

49.Londoño AF, Farner JM, Dillon M, Grab DJ, Kim Y, Scorpio DG, et al. Benidipine impairs innate immunity converting sublethal to lethal infections in a murine model of spotted fever rickettsiosis. PLoS Negl Trop Dis. 2024;18(2):e0011993.

50.Rymaszewska A, Piotrowski M. Rickettsia Species: Genetic Variability, Vectors, and Rickettsiosis—A Review. Pathogens. 2024;13:661.

51.Diop A, El Karkouri K, Raoult D, Fournier PE. Genome sequence-based criteria for demarcation and definition of species in the genus Rickettsia. Int J Syst Evol Microbiol. 2020;70:1738–50.

52.Voss OH, Maldonado J, Gaytan H, Ullah S, Mesra M, Rahman MS. The phosphatidylserine receptor CD300f modulates engulfment of Rickettsia species by macrophages. Infect Immun. 2025;93:e00686-19.

53.Arboleda M, Acevedo-Gutiérrez LY, Ávila A, Ospina D, Díaz FJ, Walker DH, et al. Human Rickettsiosis Caused by Rickettsia parkeri Strain Atlantic Rainforest, Urabá, Colombia. Emerg Infect Dis. 2020;26:3086–9.

54.Xing F, Deng C, Huang J, Yuan Y, Luo Z, Lo SKF, et al. Usefulness of next-generation sequencing for laboratory diagnosis of rickettsiosis. PLoS Negl Trop Dis. 2024;18:e0012546.

55.Brouqui P, Bacellar F, Baranton G, Birtles RJ, Bjoërsdorff A, Blanco JR, et al. Guidelines for the diagnosis of tick-borne bacterial diseases in Europe. Clin Microbiol Infect. 2004;10:1108–33.

56.Hansen K, Lebech AM. Lyme neuroborreliosis: a new sensitive diagnostic assay for intrathecal synthesis of Borrelia burgdorferi specific immuno globulin G, A, and M. Ann Neurol. 1991;30(2):197–205.

57.Rallis TM, Kriesel JD, Dumler JS, Wagoner LE, Wright ED, Spruance SL. Rocky Mountain spotted fever following cardiac transplantation. West J Med. 1993;158:625–8.

58.Sosa-Gutiérrez CG, Solorzano-Santos F, Walker DH, Torres J, Serrano CA, Gordillo-Perez G. Fatal monocytic ehrlichiosis in woman, Mexico, 2013. Emerg Infect Dis. 2016;22:871–4.

59.Dzul-Rosado K, Peniche-Lara G, R. Tello-Martín, J. Zavala-Velázquez, R. de Campos Pacheco, M.B. Labruna, et al. Rickettsia rickettsii isolation from naturally infected Amblyomma parvum ticks by centrifugation in a 24-well culture plate technique. Open Vet J. 2013;3(2):101–5.

60.Londoño AF, Díaz FJ, Valbuena G, Gazi M, Labruna MB, Hidalgo M, et al. Infection of Amblyomma ovale by Rickettsia sp. strain Atlantic rainforest, Colombia. Ticks Tick Borne Dis. 2014;5:672–5.

61.Martínez-Medina MA, Álvarez-Hernández G, Padilla-Zamudio JG, Rojas-Guerra MG. Fiebre Manchada de las Montañas Rocosas en niños: consideraciones clínicas y epidemiológicas. Gac Med Mex. 2007;143:137–40.

62.Martínez-Medina MA, Padilla-Zamudio G, Solís-Gallardo LP, Guevara-Tovar M. Fiebre manchada de las Montañas Rocosas informe de dos casos. Gac Med Mex. 2005;141:309–12.

63.Marín BE, Hoffmann A. Un caso probable de parálisis por garrapatas en la Sierra Sur de Oaxaca en la Finca El Sinaí. In: Romero N., J., E.G. Estrada V. y A. Equihua M (Eds.). Entomología Mexicana. Sociedad Mexicana de Entomología, Ciudad de México; 2002. p. 64-6.

64.Montiel-Parra G, Fuentes-Moreno H, Vargas M. Primer registro de Ixodes cookei (Acari: Ixodidae) para México. Rev Mex Biodivers. 2007;78:206-6.

65.Sosa-Gutiérrez CG, Vargas M, Torres J, Gordillo-Pérez MG. Tick-borne rickettsial pathogens in rodents from Mexico. J Biomed Sci Eng. 2014;7:884–9.

66.Tinoco-Gracia L, Quiroz-Romero H, Quintero-Martínez MT, et al. Prevalence of Rhipicephalus sanguineus ticks on dogs in a region on the Mexico–USA border. Vet Res. 2009;164:59–61.

67.Eremeeva ME, Zambrano ML, Anaya L, et al. Rickettsia rickettsii in Rhipicephalus ticks, Mexicali, Mexico. J Med Entomol. 2011;48:418–21.

68.Dykova I, Veverkova M, Fiala I, Machackova B, Peckova H. Nuclearia pattersoni sp. (Filosea) a new species of amphizoic amoeba isolated from gillsof roach (Rutilus rutilus), and its rickettsial endosymbiont. Folia Parasitol. 2003;50:161–70.

69.Santibáñez S, Portillo A, Palomar A.M., Oteo J.A. Isolation of Rickettsia amblyommatis in HUVEC line. New Microbes New Infect. 2018;21:117–21.

70.Lamason RL, Kafai NM, Welch MD. A streamlined method for transposon mutagenesis of Rickettsia parkeri yields numerous mutations that impact infection. PLoS One. 2018;13:e0197012.

71.Probert PM, Hotopp JD, Graves S, Karpathy SE, Eremeeva ME. Rocky Mountain spotted fever caused by Rickettsia rickettsii in California. Emerg Infect Dis. 2024;30:1367-9.

72.Dykova I, Veverkova M, Fiala I, Machackova B, Peckova H. Nuclearia pattersoni sp. (Filosea) a new species of amphizoic amoeba isolated from gillsof roach (Rutilus rutilus), and its rickettsial endosymbiont. Folia Parasitol. 2003;50:161–70.