BORRELIA SPP.

AETIOLOGY

Classification of the causative agent

Borrelia spp. include the agents of Lyme disease and tickborne relapsing fever in humans and animals. They are Gram-negative spirochaetes. There are 42 species in the *Borrelia* genus: 21 in the tickborne relapsing fever (TBRF) group, 20 in the Lyme-Borreliosis (LB) group, and one (*B. turcica*) associated with reptiles. The LB groups are split into *B. burgdorferi* sensu stricto (s. s.) and *B. burgdorferi* sensu lato (s. l.). The former can cause disease in both humans and animals while the latter include *B. burgdorferi* s.s. mainly causes disease in humans. The primary cause of pathology in the LB group for both humans and animals is *B. burgdorferi* s. s. *Borrelia turcica* has unknown pathology in reptiles, wildlife, domestic animals, or humans.

These bacteria are spread by several tick species. Though clinical disease in wildlife is limited with Lyme and TBRF, it is important to consider their role in the transmission of these bacteria to domestic animals and humans.

For the purposes of this technical card, *B. burgdorferi* under the “Lyme Borreliosis” sections refers to *B. burgdorferi* s. s. Other Borrelia species mentioned under the “Lyme Borreliosis” sections should be assumed to be part of the *B. burgdorferi* s. l. group.

Resistance to physical and chemical action

Temperature: Survives for 1 week in blood clots at room temperature, many months at 4°C, and indefinitely at <20°C; grows at 30-35°C in a microaerophilic environment; decreased survival time at ≳40°C

pH: Optimal pH of 7.6; able to survive at pH 4.0-9.0

Chemicals/Disinfectants: Killed by 70% ethanol, 1% sodium hypochlorite

Survival: Sensitive to UV light

EPIDEMIOLOGY

The epidemiology of *Borrelia* spp. is generally related to the life cycle of their vectors. Transmission of the bacteria to a host can occur at different life stages, depending on the tick species. The primary tick species that spread *Borrelia* spp. infecting and causing clinical disease in wildlife are *Ixodes* and *Argas*.

Ixodes spp., one of the vectors for *B. burgdorferi*, are three-host ticks. The larval and nymphal ticks feed on the reservoir host and acquire the pathogen. Nymphal ticks then feed on humans or other animals and spread the pathogen to their hosts. It is also possible for adult ticks to transmit bacteria as well, though it is less common. As adults, *Ixodes* spp. are maintained on deer. Large mammals such as deer are incompetent hosts for Lyme borreliosis, though ticks can transmit the bacteria to each other on these hosts by co-feeding.

The soft-bodied ticks - *Argas* and *Ornithodoros* spp. - have multiple nymphal stages and may feed on several different hosts such as rodents and birds. They can acquire and transmit *Borrelia* spp. at any point in their development. *B. anserina* can be transovarially transmitted in *Argas* spp. *Ornithodoros* spp. transmit several *Borrelia* spp. (e.g., *B. hermsii*, *B. turicatae*) that cause TBRF in humans. Wild rodents and birds can serve as reservoir hosts for the bacteria.

Rhipicephalus spp. (e.g., *R. annulatus, R. microplus*) are one-host tick species that spread *B. theileri* to domestic cattle, causing bovine borreliosis.

Hosts

- *B. anserina* (*Argas* spp.)
    - African grey parrots (*Psittacus erithacus*)
    - Canaries (Family *Fringilidae*)
    - Chickens (*Gallus gallus*)
    - Ducks and geese (Family *Anatidae*)
    - Northern spotted owls (*Strix occidentalis*)
    - Pheasants (Family *Phasianidae*)
    - Turkeys (*Meleagris* spp.)
- *B. burgdorferi* (*Ixodes* spp.)
    - Reservoir hosts (North America)
        - Eastern chipmunks (*Tamia striatus*)
        - Raccoons (*Procio lotor*)
        - White-footed mice (*Peromyscus leucopus*)
    - Reservoir hosts (Europe)
        - European hedgehogs (*Erinaceus europaeus*)
        - Voles (*Clethrionomys glareolus*, *Apodemus* spp.)
    - Bank voles (*Clethrionomys glareolus*)
    - Cattle (*Bos taurus*)
    - Dogs (*Canis familiaris*)
    - Horses (*Equus caballus ferus*)
    - Red fox (*Vulpes vulpes*)
    - Reindeer (*Rangifer tarandus*)
    - Wood mice (*A. sylvaticus*)
    - Yellow-necked field mice (*Apodemus flavicollis*)

Transmission

- Infected ticks transmit bacteria to their hosts via coxal secretions or saliva from bite
- Outbreaks of *B. anserina* in birds have occurred due to coprophagia and cannibalism
    - Also spread by faeces, excreta, and tissues from infected birds
- *B. burgdorferi* may be spread by direct or indirect co-feeding on host

Sources

- Infected ticks
- Faeces, excreta, and tissues from infected birds (*B. anserina*)

Occurrence

Several Lyme and TBRF *Borrelia* spp. have regional and tick host specificities. Examples will be provided in the following paragraphs.

Lyme Borreliosis

Lyme disease was first identified in humans in Lyme, Connecticut in 1975, when an epidemiological investigation revealed an abnormally high incidence of rheumatoid arthritis in children, some of whom presented with a characteristic erythema migrans rash. *Ixodes* spp. were subsequently identified as potential vectors and *Borrelia* was identified as the infective agent in 1981.

B. burgdorferi exists in Europe, Russia, Japan, and New South Wales (Australia). In the United States, *B. burgdorferi* is endemic to Minnesota, Wisconsin, the Pacific Coast, and the Atlantic Coast. *Ixodes ricinus* spreads the bacteria throughout Mediterranean countries, northern Africa, parts of Russia, the United Kingdom, and Scandinavian countries. *I. persulcatus* is another vector in Eastern European countries and

Japan. *B. garinii* and *B. afzelii* are more prevalent in Asia than *B. burgdorferi*. Seabirds harbour *B. garinii* which is spread by *I. uriae*, a tick that primarily feeds on seabirds.

Worldwide, it is thought the spread of Lyme disease is secondary to tick habitat expansion due to climate change. In the United States, a rise in deer populations and movement of people to rural areas is thought to contribute to Lyme disease spread due to increased interaction between deer and humans. Wild avian species spread both the bacteria and ticks to new geographic locations via their migration routes.

In the western United States, the western fence lizard (*Sceloporus occidentalis*) is host to the larval and nymphal stages of the western black-legged tick (*Ixodes pacificus*). While it acts as a host to this tick species it is not a reservoir host to the bacteria, which is thought to be due to borreliacidal activity of its blood.

Tickborne Relapsing Fever

B. anserina was first identified in Russia as goose septicaemia in 1891. The bacterium is present in domestic and captive birds in tropical and subtropical areas of the world, such as South America (Colombia, Venezuela, Ecuador, Argentina, Brazil), Central America, Indonesia, Australia, India, the Middle East, West and North Africa, and the southwestern United States. In Europe, other TBRF *Borrelia* spp. are mainly found in Mediterranean countries.

For more recent, detailed information on the occurrence of this disease worldwide, see the OIE World Animal Health Information System - Wild (WAHIS-Wild) Interface [http://www.oie.int/wahis_2/public/wahidwild.php/Index].

DIAGNOSIS

The transmission cycle of *B. burgdorferi* is complex. The bacteria enters the tick midgut after feeding on an infected host. This results in the protein OspA being upregulated and interacting with a protein in the tick midgut called TROSPA; the bacteria binds in the midgut to prevent it from being digested by tick digestive enzymes. OspC expression allows the bacteria to exit the midgut and make its way to the tick salivary gland and subsequently to the host during feeding. In the vertebrate host, the OspC protein allows the bacteria to burrow into the skin, where it then travels to other tissues. The life cycle of TBRF *Borrelia* spp. is not well-characterised.

For *B. burgdorferi*, animals may be seropositive without clinical signs. There are higher mortality rates in juvenile than adult birds due to *B. anserina*. Clinical signs appear after about 1-2 weeks after infection.

Clinical diagnosis

Lyme Borreliosis

Lyme *Borrelia* spp. have been isolated from several wild mammal and bird species. However, reports of clinical disease are infrequent. White-footed mice (*Peromyscus leucopus*) have been reported with erythema of ear pinnae, hind limb paresis, circling, trembling, and incoordination. A suspected *Borrelia* sp. infection in a reindeer herd resulted in musculoskeletal problems. A *Borrelia* infection in a hedgehog caused an erythema migrans rash, anorexia, ataxia, stiff gait, joint effusion and death. A red fox infected with *B. afzelii* experienced inflammation of the eye, kidney, and liver.

Tickborne Relapsing Fever

Birds with TBRF present with fever, anorexia, depression, ruffled feathers, and green diarrhoea. It is thought that infection with TBRF agents in wildlife is underreported. Mortality in a bat has been reported due to infection with a TBRF agent; it was distinct from but most closely related to *B. duttonii*, *B. crocidurae*, and *B. recurrentis*. It died after a few days of rehabilitation.

Lesions

Lyme Borreliosis

- Dusky-footed woodrats (*Neotoma fuscipes*)
    - Synovitis
    - Myositis
    - Myocarditis
- White-footed mice (*Peromyscus leucopus*)
    - Pneumonitis
    - Encephalitis
    - Perivascular lymphoplasmacytic infiltrates of kidneys and liver

Tickborne Relapsing Fever

- Bats (*Pipistrellus* spp.)
    - Multifocal necrosis of the liver with vacuolation of hepatocytes with macrophage infiltration
    - Hepatomegaly
    - Splenomegaly
    - Pale, enlarged adrenal glands with haemorrhage
    - Congested lungs infiltrated by inflammatory cells
    - Granulocytes in blood vessels
    - Extramedullary haemopoiesis of the spleen
    - Speckling in kidney cortices
    - Enlarged cranial thoracic lymph nodes
- Birds
    - Hepatomegaly with necrotic foci, haemosiderosis, erythrophagocytosis
    - Enlarged kidneys
    - Splenomegaly with mottling, haemorrhage, and haemosiderosis
    - Haemorrhages of ventriculus and proventriculus
    - Mononuclear phagocyte hyperplasia
    - Erythrophagocytosis
    - Spirochaetes may be visualised in blood vessels, intercellular spaces, and bile canaliculi using silver-stained tissue sections

Differential diagnoses

- Birds
    - *Plasmodium*
    - *Leukocytozoon*
    - *Haemoproteus*
    - *Aegyptianella* spp.
    - Heavy metal toxicity
    - Influenza
    - Pasteurellosis/fowl cholera
    - Marek's disease
- Mammals
    - Musculoskeletal
        - Anaplasmosis
        - Babesiosis
        - Rocky Mountain Spotted Fever
        - Rheumatoid arthritis, osteoarthritis
        - Septic arthritis
        - Osteomyelitis
        - Polymyositis
        - Panosteitis
    - Renal disease
        - Leptospirosis

        - Toxin exposure (e.g., ethylene glycol)
    - Neurologic disease
        - Rabies
        - Meningitis, encephalitis
        - Toxin exposure (e.g., heavy metals)
        - Causes of facial nerve paralysis such as otitis media/interna, trauma
    - Listeriosis
    - Haemolysis/haemolytic anaemia
    - Bartonellosis
    - Neoplasia
    - Trauma

Laboratory diagnosis

Samples

For isolation of agent

- Synovial joint fluid
- Skin from ear punch biopsy
- Infected tissue

Serological tests

- Whole blood

Procedures

Identification of the agent

- *B. anserina*
    - Dark-field or phase contrast microscopy using 10-fold diluted blood
    - Immunofluorescence assay (IFA) on blood smear
    - Giemsa silver-stained stained blood smear
    - Bacterial growth from inoculation of infected tissue into yolk sac of 5-6-day embryonated eggs will occur after 2-3 days of incubation
    - Antigen or antibody in agar gel diffusion tests
- *B. burgdorferi*
    - Polymerase chain reaction (PCR)
    - Dark-field immunofluorescence microscopy
    - Bacterial culture
        - Ear punch biopsies from dogs and mice
        - Culture of synovial joint fluid
        - Both of these can be cultured in Barbour-Stoenner-Kelly (BSK) at 33°C
- Other *Borrelia* spp.
    - Giemsa or silver-stained stained blood smear

Serological tests

- Indirect fluorescent antibody (IFA) test
- Antibody capture enzyme-linked immunosorbent assay (ELISA)
- *B. burgdorferi* serotyping using monoclonal antibodies against OspA and OspC bacterial surface proteins
    - C6 peptide-based assay to identify antibodies to *B. burgdorferi* is used in dogs

PREVENTION AND CONTROL

Sanitary prophylaxis

- Tick control with acaricides, vegetation management, leaf litter removal, biological agents, soaps, and desiccants
- Tick preventive medication for captive animals
- Wildlife management, including permethrin-treated deer feeding stations and adequate livestock fencing

Medical prophylaxis

- Inactivated vaccines for *B. anserina* have been created from infected blood or egg-cultured *B. anserina* for commercial chickens
- Two vaccines are used in dogs to prevent Lyme disease: whole cell lysate and recombinant outer surface protein A (OspA)
- In wildlife, several experimental trials of vaccines against *B. burgdorferi* have been conducted, during which the majority of subjects produced antibodies to the bacterium
    - An OspA reservoir targeted bait vaccine (OspA-RTV) was has been used in white-footed mice that were intraperitoneally inoculated with lipidated OspA in a laboratory setting

POTENTIAL IMPACTS OF DISEASE AGENT BEYOND CLINICAL ILLNESS

Risks to public health

- *B. burgdorferi* can be transmitted to humans directly from infected ticks. There is no evidence that the bacteria can be spread directly from animals to humans.
- *B. burgdorferi* is the main cause of Lyme disease for humans in North America.
- *B. garinii* and *B. afzelii* are considered emerging Lyme disease pathogens.
- *B. duttonii* causes TBRF in eastern and central Africa; *B. crocidurae* causes TBRF in western Africa. These are spread by *Ornithodoros* tick spp.
- *B. miyamotoi* and *B. recurrentis* cause relapsing fever in humans; the latter is transmitted to humans via *Pediculus humanus* lice.

Risks to agriculture

- Ruminants infected with *B. theileri* (causing TBRF, spread by *Rhipicephalus* spp.) and cows infected with *B. burgdorferi* may experience decreased milk production.
- Hens infected with *B. anserina* may experience decreased egg production.

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The OIE will periodically update the OIE Technical Disease Cards. Please send relevant new references and proposed modifications to the OIE Science Department (scientific.dept@oie.int). Last updated 2020. Written by Samantha Gieger and Erin Furmaga with assistance from the USGS National Wildlife Health Center.