BABESIOSIS

Introduction top

Babesiosis is caused by any one of many *Babesia* species that infect a wide variety of vertebrate hosts, including domestic and wild animals, as well as man. In nature, babesias typically are transmitted biologically by ixodid ticks, but other means, such as biting flies and fomites that transfer blood from the infected carrier to a susceptible animal, may be involved in the mechanical transmission of these intraerythrocytic parasites. A list of commonly encountered babesias is presented in Table 1. Although it is possible for a single *Babesia* species to infect more than one vertebrate host, as seen in *B. microti* (rodents and man) and *B. divergens* (cattle, man, and gerbils), the general pattern is that the *Babesia* species are reasonably host specific.

This review will deal primarily with those babesias afflicting cattle. It is thought that these animals are, from an economic point of view, the most severely affected by babesial infections. Equine babesiosis and babesiosis of other animals are discussed briefly in this chapter.

Bovine Babesiosis top

(Piroplasmosis, Texas fever, redwater, tick fever)

Definition top

Bovine babesiosis is a febrile, tick-borne disease of cattle, caused by one or more protozoan parasites of the genus *Babesia* and generally characterized by extensive erythrocytic lysis leading to anemia, icterus, hemoglobinuria,and death.

There are probably at least six *Babesia* species (Table 1) responsible for bovine babesiosis. Most can be categorized as being small or large babesia. Morphological and serological differences are used to distinguish the different species. The two that are of most concern in the United States are *B. bigemina* and *B. bovis*, which are transmitted primarily by *Boophilus* ticks. These species and their vector ticks once occurred in large areas of the United States, and still occur in Mexico and throughout the tropical and subtropical areas of the Western Hemisphere.

Babesia bigemina top

Etiology top

B. bigemina (Fig. 29) is a large babesia that is pleomorphic but characteristically is seen and identified by the pear-shaped bodies joined at an acute angle within the mature erythrocyte. Round forms measure 2 µm and the pear-shaped, elongated ones are 4-5 µm (1).

History top

One of the early accounts in the United States of babesiosis dates from 1868, when a disastrous epizootic broke out among native cattle in Illinois and Indiana with the loss of 15,000 head after the importation of apparently healthy cattle from Texas (2). The mortality rate among affected cattle approached 90 percent. The fear and respect for Texas or southern cattle fever was wellfounded. Even then it was not a new disease, having been described as early as 1814. It was not, however, until much later that the cause and mode of transmission became apparent.

The classical investigations of Smith and Kilborne (1893) were the first to establish that a pathogenic protozoan (*B. bigemina*) could be transmitted by an intermediate arthropod host (*Boophilus annulatus*) (3). At that time, *Boophilus* ticks, and presumably babesiosis, occurred in the United States throughout the South, from Texas to the Atlantic States, as well as in southern California (Illustration 1) (4). In 1906, it was estimated that economic losses associated with the tick, and *B. bigemina* (probably *B. bovis* also) amounted to $130.5 million annually. In terms of present dollars, and considering the larger number of cattle now present in the South, these losses would easily exceed a billion dollars annually if ticks and babesias were left uncontrolled. A tick eradication program was essentially completed by 1943, and bovine babesiosis ceased to exist in the United States except in the quarantine buffer zone adjacent to the Mexican border (4). Babesiosis is now considered an exotic disease of cattle for the United States. This impressive accomplishment of tick eradication has never been duplicated in an area of comparable size, notwithstanding similar efforts in various parts of the world. As a result of those failures, both ticks and babesia are widely prevalent elsewhere and constitute a continuing threat to U.S. livestock.

Host Range top

Cattle are the principal hosts, but it is reported that the water buffalo and African buffalo may also become infected (11). It is possible that other ungulates are infected, but from a practical point of view, these infections are nominal and, except under unusual conditions, rare. Such hosts are probably not significant reservoirs of infection.

Babesia bigemina is widespread in cattle and occurs wherever *Boophilus* ticks are encountered, which includes North and South America, Southern Europe, Africa, Asia, and Australia (10). Babesiosis also occurs on the Caribbean and South Pacific islands. Cattle and the invertebrate tick hosts provide the major reservoir of infection. Wildlife and nonbovine hosts generally have not been incriminated.

Transmission top

Ticks acquire babesia infection during their feeding on infected animals. The infection is then passed to the ovaries, and thus the emerging larvae carry the infection. The babesias continue to develop within the larvae, and transmission usually occurs in the new host during the nymphal and adult stages. *Boophilus* *annulatus*, *B. microplus*, and *B. decoloratus* are the principal vectors of *B. bigemina* (5,6). Mechanical transmission is possible, but it is not efficient enough to maintain infection in the absence of specific tick vectors.

Incubation Period top

Natural transmission occurs by the feeding of infected nymphal and adult ticks, and evidence of infection occurs 2-3 weeks after tick infestation. Following blood inoculation, the incubation time may be 4-5 days or less, depending on the size of the exposing inoculum.

Clinical Signs top

Infection with *B. bigemina* is usually accompanied by the presence of *Boophilus* ticks. Calves normally are reasonably resistant to babesia, for the infection does not usually result in clinical disease (5). In older animals, clinical signs can be very severe; however, differences in pathogenicity may occur with various *B. bigemina* isolates associated with different geographic areas. Mahoney observed that the Australian *B. bigemina* rarely causes disease, whereas *B. bigemina* in Africa is highly pathogenic (6). Personal experience by the author suggests that *B. bigemina* as seen in the Western Hemisphere is highly pathogenic; however, it is probably less so than *B. bovis*.

The first sign is usually a high fever with rectal temperatures reaching 41.5º C (106.7º F). There is anorexia, and ruminal atony. Often the first visible appearance of infection is that the animal isolates itself from the herd, becomes uneasy, seeks shade, and may lie down. Cattle may stand with an arched back, have a roughened hair coat, and show evidence of dyspnea and tachycardia. The mucous membranes are first injected and reddened, but as erythrocytic lysis occurs, the color changes to the pallor of anemia. Anemia is a contributory factor to the weakness and loss of condition seen in cattle that survive the acute phase of the disease. The anemia may occur very rapidly, with 75 percent or more of the erythrocytes being destroyed in just a few days. This is usually associated with severe hemoglobinemia and hemoglobinuria. After onset of fever, the crisis will usually pass within a week, and if the animal survives, there is usually severe weight loss, drop in milk production, possible abortion, and a protracted recovery. Mortality is extremely variable and may reach 50 percent or higher, but in the absence of undue stress most animals will survive (5,6).

Gross Lesions top

The lungs may be edematous and congested in cattle that have died early in the course of infection. The pericardial sac may contain serosanguineous fluid and subepicardial and subendocardial petechial hemorrhages. The liver is enlarged and icteric, and the gallbladder, which may have hemorrhage on the mucous surface, is distended with thick, dark green bile. The spleen is markedly enlarged, and has a dark pulpy consistency. The abomasal and intestinal mucosa may be icteric with patches of subserosal hemorrhages. The blood is thin and watery. The urinary bladder is frequently distended, with dark, reddish-brown urine. Jaundice is commonly distributed in the connective tissue. The lymph nodes are edematous and often have petechiation.

In cattle that have suffered a more prolonged illness, acute lesions are much less conspicuous. Subepicardial petechial hemorrhages may be present, the carcass is usually emaciated and icteric, the blood is thin and watery, the intermuscular fascia is edematous, the liver yellowish-brown, and the bile may contain flakes of semisolid material. The kidneys are pale and often edematous, and the bladder may contain normal urine, depending on how long past the hemolytic crisis the necropsy is performed. Although the spleen is enlarged, the pulp is firmer than in acute babesiosis (5,6,7).

Diagnosis top

Field Diagnosis top

Fever, anemia, jaundice, and hemoglobinuria are suggestive clinical signs of babesiosis in cattle located in enzootic areas where *Boophilus* ticks occur. If these signs are also associated with erythrocytic destruction, the diagnosis of babesiosis is strengthened. A positive diagnosis requires the identification of the babesia on blood smears or either positive serologic tests or transmission experiments, or both.

Specimens for the Laboratory top

From each animal six blood smears should be made, air-dried and fixed in methanol and/or a sample of whole blood in an anticoagulant and serum should be collected.

In acute infection, *B. bigemina* can usually be detected on Giemsa-stained thin blood smears. Thick smears (8) increase the likelihood of detecting the causative organism, but the characteristic morphology is more difficult to identify with this technique. In cases of chronic infection, diagnosis is usually made using a variety of serologic tests for the detection of specific antibodies, since the organism disappears or is present in extremely low numbers soon after the acute infection.

Differential Diagnosis top

Other conditions that should be considered and may resemble babesiosis are anaplasmosis, trypanosomiasis, theileriosis, leptospirosis, bacillary hemoglobinuria, hemobartonellosis, and eperythrozoonosis.

Prognosis top

After the onset of hemoglobinuria, the prognosis is guarded. Among fully susceptible older cattle, the mortality may reach 50 percent without treatment. Among cattle raised in an area where babesiosis is endemic, few, if any, losses occur even though infection takes place (6). This phenomenon usually reflects early exposure of the neonates, when they are more resistant, resulting in varying levels of protection. Once having the infection, the bovine experiences a high level of resistance to reexposure.

Treatment top

Successful treatment of *B. bigemina* depends on early diagnosis and the prompt administration of effective drugs. There is less likelihood of success if treatment is delayed until the animal has been weakened by fever and anemia. If medication is administered early, however, success is the rule, for there are several effective compounds (Table 2) (14).

One of the first successful treatments was trypan blue. This treatment may be used to determine the type of infection present. *B. bigemina* is susceptible to trypan blue treatment, whereas *B. bovis*, is not. Generally, the small babesias are more resistant to chemotherapy. The most commonly used compounds for the treatment of babesiosis are diminazene diaceturate (3-5 mg/kg), imidocarb (1-3 mg/kg), and amicarbalide (5-10 mg/kg); however, the quinuronium and acridine derivatives are also effective (Table 2). Treatment of *B. bigemina* is so effective in some instances that radical cures occur that will eventually leave the animal susceptible to reinfection. For this reason, reduced drug levels are sometimes indicated. Imidocarb has been successfully used as a chemoprophylactic, that will prevent clinical infection for as long as 2 months but allow mild subclinical infection to occur as the drug level wanes, resulting in premunition and immunity (15,16). The relative efficacy of some the more common compounds used is shown in Table 3.

Vaccination top

The most common form of immunization against *B. bigemina* entails inoculating live organism (attenuated or virulent) into susceptible young cattle followed by chemotherapy, as needed, to modify the clinical effects; thus, coinfectious immunity or a state of premunition is induced (6). If older animals are to be so vaccinated, care may be necessary to prevent serious reactions (17,18). An attenuated organism has successfully been used in Australia (19). Such a premunition approach, although useful in endemic areas, would be less desirable in areas where the infection rate is low because this approach, in essence, establishes a large reservoir of infection.

Experimental trials with nonviable vaccines have been successfully conducted, but no commercial vaccine of this type is available at this time (6,9). After having recovered from a premunizing parasitemia cattle will have a degree of sterile immunity for a short time (20). Carrier infections, if accompanied by reexposure, as is common in endemic areas, will result in immunity that may persist for the lifetime of the animal (18). There are instances when antigen variations may occur that might challenge the immunity of a vaccinated animal. Usually, however, when animals are premunized, even variants will not produce a clinically detectable reaction (6,9).

Control and Eradication top

Preventive Measures

The oldest and probably the most effective procedure for the control of babesiosis is to control and eradicate its vector, the *Boophilus* tick (4). The eradication campaign in the United States conducted in the 1920's and 1930's relied largely on dipping all cattle every 2-3 weeks in vats charged with arsenical acaricides (4). These acaricides have been replaced by a wide variety of improved compounds, including the chlorinated hydrocarbons, carbamates, organophosphates, and natural and synthetic pyrethrins (4). In some tropical countries, tick control rather than eradication is the goal. This approach attempts to establish an equilibrium in which the tick numbers are sufficient to maintain low-level infection in the cattle and hence immunity to acute babesiosis. Care must be taken, however, to prevent the development of excessive ticks that could be responsible for livestock losses (12,13). In the absence of reinfection, the babesias gradually disappear, and the cattle become susceptible; hence, a desire exists to sustain low levels of exposure to maintain immunizing infections. Tick control in some areas has been complicated by the development of tick resistance to many of the common acaricides (4).

Sanitation and Disinfection

Aside from efforts involved in the control and elimination of the tick vector, sanitation and disinfection do not contribute to an abatement of the disease incidence in enzootic areas. As with most blood diseases, however, care is recommended in routine surgery (dehorning, castration, etc.) and needle vaccination procedures to prevent the accidental transfer of blood from one animal to another, thereby transmitting infection.

"Babesia bovis" top

Etiology top

Babesia bovis (Fig. 30) is a small pleomorphic babesia typically identified as a single body, as small round bodies, or as paired, pear-shaped bodies joined at an obtuse angle within the mature erythrocyte. The round forms measure 1-1.5 µm, and the pear-shaped bodies 1.5 by 2.4 µm in size (5,6).

History top

Soon after Smith and Kilborne's work, the presence of a second morphologically distinct small babesia of cattle occurring in Argentina was identified as *B. argentina*. This was later determined to be synonymous with *B. bovis* (21). Rees in 1930 described a small babesia in Louisiana that he determined to be *B. bovis* (21). If one studies the early drawings of Smith and Kilborne, it is evident that both *B. bigemina* and *B. bovis* were present even then. The history of this organism closely follows that of *B. bigemina*, and it is sometimes difficult to distinguish one from the other in the early literature.

Host Range top

Although cattle are the principal hosts, it is probable that infections can be maintained in other ungulates such as buffalo (11). There are reports in the literature of human cases due to *B. bovis* (24).

Geographic Distribution top

Babesia bovis usually occurs in the same areas a *B. bigemina* and in association with *Boophilus* ticks but has been described in some parts of Europe where *Boophilus* does not occur, which suggests other vectors.

Transmission top

The same ticks (*B. annulatus*, *B. microplus*) that transmit *B. bigemina* are usually capable of transmitting *B. bovis*. The tick *B. decoloratus*, which is widely distributed in Africa, does not appear to transmit *B. bovis* even though it readily transmits *B. bigemina* (9). There are reports from Europe of B. bovis, for which the vector is thought to be *Ixodes ricinus* (11,23).

Incubation Period top

B. bovis has a longer incubation time than does *B. bigemina*, but since *B. bovis* is transmitted by the larval stage of the vector rather than by the nymphal and adult stages, *B. bovis* prepatency (measured from the time of tick infestation) is only slightly longer than that of *B. bigemina*. With blood inoculation, the incubation time is usually 10-14 days; however, this can be shortened by large inoculums.

Clinical Signs top

Infections of *B. bovis* resemble, in many respects, those seen with *B. bigemina*, but there are some characteristic differences. Hemoglobinuria and hemoglobinemia are not as consistently seen in infections with *B. bovis*, although they may occur (5,6). The level of anemia is frequently less severe, but central nervous system involvement is more common. It is generally conceded that *B. bovis* is the more virulent of the two organisms. This is particularly so in Australia and to a lesser extent in Africa and the Western Hemisphere (6).

Animals commonly develop incoordination and depression and go down with the head extended but later thrown back and have involuntary movement of the legs. These signs are followed by death. Whereas the packed cell volume (PCV) in most fatal infections with *B. bigemina* will be well below 10 percent, death commonly occurs with *B. bovis* when the PCV is 12 percent or higher. When hemoglobinuria is seen, the color is not nearly so dark, nor is the plasma following PCV determination so red. The observed parasitemias in peripheral blood are usually much lower with *B. bovis* than with *B. bigemina*.

Gross Lesions top

Changes similar to those described for *B. bigemina* are apparent.

Diagnosis top

Field Diagnosis top

Fever, anemia, jaundice, and hemoglobinuria are suggestive clinical signs of babesiosis in cattle located in enzootic areas where *Boophilus* ticks occur. If these signs are also associated with erythrocytic destruction, the diagnosis of babesiosis is strengthened. A positive diagnosis requires the identification of the babesia on blood smears or either positive serologic tests, or transmission experiments, or both. In addition, a technique of brain biopsies has been described that has proven very useful in detecting and diagnosing *B. bovis* infections (9,22). The characteristic low parasitemias in the circulating blood make this technique very useful in improving the chances of seeing the organism. There is a marked concentration of infected erythrocytes in the capillaries of the brain.

Specimens for the Laboratory top

From each animal six blood smears should be made, air-dried and fixed in methanol and/or a sample of whole blood in an anticoagulant and serum should be collected. Serologic diagnostic techniques are similar to those described for *B. bigemina*. Presently, immunofluorescence assay is the test of choice in the serologic diagnosis of *B. bovis* (9).

Differential Diagnosis top

In addition to those conditions mentioned for *B. bigemina*, a differential diagnosis of *B. bovis* infection must include diseases producing central nervous system (CNS) involvement such as rabies, other encephalitides, or toxic effects that would produce similar CNS changes.

Prognosis top

Once CNS signs become pronounced, the prognosis is poor. Generally, *B. bovis* produces a somewhat more severe clinical response than does *B. bigemina*.

Treatment top

Chemotherapy is generally effective, with essentially the same drugs as used for *B. bigemina*. *B. bovis* is usually somewhat more difficult to treat, and a second treatment, or slightly increased dose rates, may be desirable. Trypan blue is not effective against *B. bovis* (14). Imidocarb has been reported to induce radical cures in vertebrate hosts. *Babesia bovis*-infected *B. annulatus* ticks, when placed on animals recently treated with imidocarb, apparently lost their infectivity, for their progeny failed to transmit infection (15). Tick infection remained following imidocarb treatment in a similar experiment with *B. bigemina* in *B. decoloratus* (25).

Vaccination top

Vaccines are used in a number of places where babesiosis is endemic. Repeated passage of *B. bovis* in splenectomized calves results in the attenuation of the organism (9,26). For many years, this attenuated vaccine has been produced and successfully used in Australia for the prevention of *B. bovis* (6). In some cattle (older, and producing dairy cows), chemotherapy may be indicated, but usually the vaccine may be used without treatment.

The development of in vitro techniques for the cultivation of *B. bovis* on bovine erythrocytes has led to the isolation of soluble antigens, which, when combined with adjuvants, have proven immunogenic (27,28). These noninfectious vaccines, although they do not prevent infection, appear to be responsible for moderating the effects of infection. They do not produce as high a level of protection as is seen with premunizing vaccines but are safe and do not yield carriers. In some instances, these vaccines, although protective against homologous challenge, may not protect against immunologic variants.

The continuous in vitro passage of *B. bovis* has been shown to induce a level of attenuation similar to that seen with the passage of the organism in splenectomized calves. Infection with this attenuated organism has been reported to prevent clinical infection following a challenge with virulent *B. bovis* (29,30).

Control and Eradication top

Eradication of the *Boophilus* vectors would eliminate transmission of *B. bovis* which, over a period of time, would lead to its eradication.

Sanitation and Disinfection

Aside from the efforts involved in the control and elimination of the tick vector, sanitation and disinfection do not contribute to an abatement of the disease incidence in enzootic areas. As with most blood diseases, however, care is recommended in routine surgery (dehorning, castration, etc.) and needle vaccination procedures to prevent the accidental transfer of blood from one animal to another, thereby transmitting infection.

Other Bovine Babesias top

Babesia divergens appears to be a serious pathogen for cattle in the United

Kingdom and northern Europe (11). It is a small species that morphologically resembles *B. bovis* but is slightly smaller and tends to be located at the periphery or margins of the infected erythrocyte. It is transmitted by *Ixodes ricinus*, which becomes infected when the adult feeds on either a carrier or an acutely infected host. All stages of the F1 and sometime F2 generation are infective and capable of transmission (11).

Babesia divergens produces a disease syndrome similar to *B. bigemina* and *B. bovis*; however, the cerebral form is rarely seen. Treatment with those babesiacides previously discussed is effective.

The presence of *Ixodes* ticks (*I. scapularis*, *I. pacificus*, and *I. dammini*) in the United States suggests the potential for this babesia to become established here. Consequently, *B. divergens* is a pathogen that should not be ignored.

Babesia jakimovi (a large species) is the causal agent of Siberian piroplasmosis in cattle. It can also infect the Tartarean roe deer, Asian elk, and reindeer. It appears to be transmitted transovarially by *I. ricinus*, but mechanical transmission by gadflies is also suggested. Signs of infection and response to treatment closely resemble *B. bigemina* (11).

Babesia major is a large species only slightly smaller than *B. bigemina*. This babesia is transmitted by *Haemaphysalis punctata* and occurs in the United Kingdom, and northern Europe (11). It is essentially nonpathogenic but can be induced to produce clinical effects and even death by serial passage in splenectomized calves.

Babesia ovate, a large species, has been described in Japan. It is apparently serologically distinct from *B. bigemina*. It is only mildly pathogenic and responds to the same therapy used against *B. bigemina* (31). Transmission in Japan is by the larvae of *Haemaphysalis longicornis*. No immunity or cross-protection occurs with *B. bigemina*, *B. bovis*, or *B. major*. Serologically it appears to be a distinct species.

Equine Babesiosis top

(Equine Piroplasmosis)

Definition top

Equine babesiosis is a febrile tick-borne disease of horses caused by either *Babesia caballi* (Fig. 31), *B. equi* (Fig. 32) or both and is generally characterized by erythrocytolysis leading to anemia, icterus, hemoglobinuria, and death.

Geographic Distribution top

Equine babesiosis is widely distributed throughout the tropics and subtropics and to a lesser extent is known to occur in temperate regions.

Transmission top

Babesia caballi is transmitted by ticks of the genera *Dermacentor*, *Hyalomma*, and *Rhipicephalus* and is passed transovarially from one tick generation to the next. Experimental transmission of *B. caballi* under laboratory conditions has been reported using *Dermacentor nitens*, *D. albipictus*, and *D. variabilis* (9). The widespread prevalence of these ticks (*D. albipictus* and *D. variabilis*), plus the presence or past presence of *B. caballi* in the United States (32), creates an unanswered question of why *B. caballi* has not become more widespread in the United States. Transmission of *B. equi* appears only to occur transstadially (33). The vector or vectors of *B. equi* have not been identified in the Western Hemisphere. Elsewhere, ticks of the genera *Dermacentor*, *Hyalomma*, and *Rhipicephalus* appear to be involved.

Clinical Signs top

The severity of clinical response is variable, and in many cases spontaneous recovery may occur following a febrile response with no marked hemoglobinuria or anemia (11). Other reports describe the response as more like that seen in cattle babesiosis.

Diagnosis top

A positive diagnosis requires the identification of the babesia on blood smears, or positive serologic tests.

Specimens for the Laboratory top

From each animal six blood smears should be made, air-dried and fixed in methanol and/or a sample of whole blood in an anticoagulant and serum should be collected.

Treatment top

Both *B. caballi* and *B. equi* respond to the babesiacidal drugs (Table 2), but *B. equi* is more refractory to treatment than *B. caballi* (14). Imidocarb appears to be the drug of choice for eliminating carrier status of infected horses. In the case of *B. caballi*, .2 mg/kg given two times at a 24-hour interval appears effective. For the same effect in *B. equi*-infected horses, 4 mg/kg is given four times at 72-hour intervals (14). This amount of drug approaches the lethal dose for 50 percent of the inoculated group (LD_{50}) of 32 mg/kg when given in two 16 mg/kg doses at 24-hour intervals (36). Side effects characterized by restlessness, abdominal pain, sweating, rolling, heavy breathing, etc., are not uncommon following imidocarb treatment at these higher levels.

Vaccination top

No efficacious vaccine for equine babesiosis is available.

Control and Eradication top

Preventive Measures

Once a horse is infected, the carrier status may persist for an extended period during which the carrier horse may act as reservoirs of infection. To prevent the introduction of equine babesiosis into areas free of infection, restrictive measures are sometimes imposed on imported horses.

Sanitation and Disinfection

Aside from measures involved in the control and elimination of the tick vector, sanitation and disinfection do not contribute to an abatement of the disease incidence in enzootic areas. As with most blood diseases, however, care is recommended in routine surgery (castration, etc.) and needle vaccination procedures to prevent the accidental transfer of blood from one animal to another, thereby transmitting infection.

Babesiosis of Other Domestic Animals top

Sheep and Goats top

Babesia motasi, a large species resembling *B. bigemina* morphologically, is infective for sheep and is transmitted by ticks of the genera *Haemaphysalis* and *Rhipicephalus*. This organism is widespread in the Old World, having been identified in Europe, the Middle East, the former Soviet Union, Southeast Asia, and

Africa (11). *B. motasi* produces a mild clinical response characterized by fever and anemia but alone is rarely responsible for significant death losses. Some strains are transmissible to goats, but this is not a consistent observation.

Babesia ovis is a small species observed in sheep and goats and occurs as a pathogenic entity in southern Europe and the Middle East (11). *Rhipicephalus* bursa has been shown to be a vector for this parasite, and *I. ricinus* and *D. reticulatus* are suspected vectors. The signs of infection may resemble those described for cattle with a febrile response, anemia, icterus, edema, and hemoglobinuria. Infections are usually mild and often are inapparent.

Both *B. motasi* and *B. ovis* respond to one or more those babesiacidal drugs referred to in Table 2 (14). Information on these babesias is limited, and few serological and cross-immunological studies have been made to clarify the identity of these intraerythrocytic parasites of sheep and goats.

Swine top

Both *Babesia trautmanni* (large) and *B. perroncitol* (small) occur in swine and, on occasion, are responsible for serious losses following infections, producing signs not unlike those described for cattle (11). Swine babesiosis has been described in the former Soviet Union, southern Europe, and Africa. In Africa, the wild pigs (warthogs and bush pigs) are thought to be reservoirs. Several ticks (species of the genera, *Boophilus*, *Hyalomma*, and *Rhipicephalus*) are suspected as possible vectors. These infections generally respond to chemotherapy with those drugs referred to in Table 2 (14).

Other Species top

An array of other babesia species exist, and a great number of vertebrate species are infected by one or more of these intraerythrocytic parasites. Wildlife are also involved, but because these babesias are often relatively nonpathogenic, they frequently go unnoticed.

Public Health top

Of recent interest has been the occurrence of babesiosis in man. At one time these human infections were thought to occur only in splenectomized individuals, or those who were otherwise immunosuppressed. This is not, however, the case where *B. microti.*, transmitted by *I. dammini* (24), is involved.

GUIDE TO THE LITERATURE top

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Table 1. **Recognized babesia species of domestic animals**

Organism	Animals affected	Morphology of organism	Vectors
B. bigemina[1]	Cattle	4.5 by 2.5 µm (Large, round and pryiform, acute angle)	*Boophilus annulatus, B. decoratus, B. microplus*
B. bovis[2]	Cattle	2.4 by 1.5 µm (small, more rounded obtuse angle)	*B. annulatus*, *B. microplus, Ixodes* spp. (?)
B. divergens	Cattle	1.5 by 0.4 µm (small, narrow and obtuse angle)	*Ixodes ricinus*
B. major	Cattle	2.6 by1.5 µm (large round & pyriform)	*Haemaphysalis punctata*
B. jakimovi	Cattle and wild ruminants	Similar to *B. major*	*I. ricinus*
B. ovata	Cattle	Similar to *B. bigemina*	*H. longicornis*

B. caballi	Horses	Similar to *B. bigemina*	*Dermacentor, Hyalomma*, and *Rhipicephalus* spp
B. equi	Horses	1.0-2.0 µm (small and rounded, Maltese cross is common)	*Dermacentor*, *Hyalomma*
B. motasi	Sheep and goats	Simlar to *B. bigemina*	*D. silvarum* (?), *R. bursa, Haemaphysalis* spp
B. ovis	Sheep and goats	1.5 by 1.0 µm (small, rounded, obtuse)	*I. ricinus* (?), *D. reticulatus* (?). *R bursa*
B. trautmanni	Swine	3.5x2.0 µm (large, narrow and long, acute angle)	*R. sanguineus* (?), *Boophilus, Hyalomma*, *Dermacentor* spp, (?)
B. perroncitoi	Swine	0.7-2.0 µm (small and more rounded)	Vectors unknown

(?) Suspected vectors

1. B. bigemina, producing detectable parasitemias.

2. Synonyms *B. berbera*, and *B. argendna*

Table 2**. Products used to treat babesiosis successfully**

Compound or compound group	Proprietary name

Acridine derivatives Acriflavine hydrochloride (Euflavine, Trypaflavine)	Gonacrine[1]
Blue Azo-Naphthalene dyes Trypan blue	Congo Blue, Niagara Blue
Qiamidine derivative Aromatic: Diminazene diaceturate Pentamidine diisethionate Phenamidine diisethionate Carbanilide: Amicarbalide diisethionate Imidocarb dipropionate	Berenil[2] , Ganaseg[3] Lomidine[1] Lomidine[1] Diampron[1] Imizol[4]
Quinoline derivatives Quinuronium sulfate	Acaprin[5] Akiron Pirevan Piroplasmin Babesan[6]

1. May and Baker Ud., Dagenham, England
2. Farbwerke-Hoechst AG, Frankfurt, Germany
3. Squibb Mathieson, E. R. Squibb and Sons de Mexico, Mexico City, Mexico
4. Pitman-Moore, Europe, Middlesex, England
5. Ludabel Farbenfabriken, Bayer, Leverkusen, Germany
6. Imperial Chemical Industries Ud., Macclesfield, 2
7. Cheshire, England

Table 3. **Relative efficacy of the more commonly used babesiacidal compounds**

Diminazene

B. bigemina ++++

B. bovis +++

B. divergens ++

B. caballi +++

B. equi ++

Imidocarb

B. bigemina ++++

B. bovis +++

B. divergens +++

B. caballi ++++

B. equi ++

Amicarbalide

B. bigemina ++++

B. bovis ++

B. divergens ++

B. caballi +++

B. equi +

Phenamidine

B. bigemina ++

B. bovis ++

B. divergens +++

B. caballi ++

B. equi

Quinuronium

B. bigemina +++

B. bovis ++

B. divergens +

B. caballi ++

B. equi —

Trypan Blue

B. bigemina ++

B. bovis —

B. divergens —

B. caballi ++

B. equi —

Pentamidine

B. bigemina ++

B. bovis

B. divergens

B. caballi

B. equi

—: not effective.

Information provided in Tables 2 and 3 does not constitute an endorsement by the USAHA. State and Federal authorities should be contacted before use.
