Equine Piroplasmosis

Equine Babesiosis, Equine Theileriosis, Biliary Fever

Last Updated: December 2018

Importance

Equine piroplasmosis is a tick-borne protozoal disease that affects horses and other equids. The consequences of infection may include asymptomatic carriage, an acute and potentially life-threatening illness, or chronic disease with vague clinical signs such as reduced exercise tolerance. Piroplasmosis is a significant constraint to the international movement of equids, limiting both trade and participation in international competitions. Approximately 90% of equids worldwide are thought to live in areas where this disease is endemic, and detecting asymptomatic carriers can be difficult. In particular, the complement fixation test used for screening imported animals in the past had a significant number of false negative results. Some asymptomatic carriers screened with this test may now live in areas thought to be piroplasmosis-free. Such carriers can transmit this disease to other equids through tick vectors or procedures that transmit blood, including the reuse of needles.

Etiology

Equine piroplasmosis can be caused by two protozoa, *Babesia caballi* and *Theileria equi* (formerly *Babesia equi*), both members of the phylum Apicomplexa and order Piroplasmida. *T. equi* is a very diverse species and has been divided into at least 3 major genotypes, A through C. Concurrent infections with *B. caballi* and T. *equi* are possible. An organism related to *T. equi* was described in North American horses in 2018 and proposed as a new species, *Theileria haneyi*. Its clinical significance is currently unclear.

Species of *Babesia* and *Theileria* that are normally found in other animal hosts have been reported occasionally in equids.

Species Affected

T. equi and *B. caballi* affect equids including horses (*Equus caballus*), Przewalski's horses (*Equus ferus przewalskii*), mules, donkeys and zebras. Maintenance hosts include domesticated and wild equids, with zebras serving as an important reservoir in Africa. All three species of zebra - plains zebra (*Equus quagga*), mountain zebra (*Equus zebra*) and Grevy's zebra (*Equus grevyi*) - can be infected in nature.

Nucleic acids of *T. equi* and *B. caballi* have also been found in significant numbers of dromedary camels, and sporadically in dogs A few infected dogs had illnesses thought to be caused by these organisms, but the clinical significance remains to be determined in camels. There are also rare reports of nucleic acids in other species including *T. equi* in a sheep, a goat, a cow, a South American tapir (*Tapirus terrestris*) and a South American rodent (*Thrichomys fosteri*); and *B. caballi* in crab-eating foxes (*Cerdocyon thous*). Organisms that appear to be related to *T. equi* but were not definitively identified have been described in additional species such as coatis (*Nasua nasua*), waterbuck (*Kobus defassa*) and a Malayan tapir (*Tapirus indicus*).

Zoonotic potential

Babesia and *Theileria* do not seem to be entirely species-specific, and some organisms occasionally infect animals other than their usual host. Human babesiosis is still incompletely understood, but *B. caballi* and *T. equi* are not thought to be significant human pathogens. While there have been suggestions that these organisms might have caused a few infections in the past, species identification at the time was not necessarily definitive. One recent survey found antibodies to *T. equi* in 6% of veterinarians and <1% of the general public in Italy. Virological evidence for infection was not assessed in this study, and serological cross-reactivity with other organisms is possible.

Geographic Distribution

The parasites that cause equine piroplasmosis are endemic in parts of Africa, the Middle East, Asia, Central and South America, Mexico, the Caribbean and southern Europe. Some countries, including Australia, New Zealand, Canada, Japan and parts of Europe, are thought to be free of this disease. Infected equids have occasionally

The Center for Food Security & Public Health

Institute for International Cooperation in Animal Biologics

Iowa State University College of Veterinary Medicine

OIE Collaborating Centre for
- Diagnosis of Animal Disease and Vaccine Evaluation in the Americas
- Day-One Veterinary Competencies and Continuing Education

USDA

been identified in piroplasmosis-free countries, generally as the result of either illegal importation or asymptomatic carriers that were not detected during import testing. The latter was more prevalent among horses imported in the past, when complement fixation, which has a significant risk of false negatives, was prescribed for international trade. Infected equids are found periodically in the U.S., which is otherwise thought to be free of equine piroplasmosis, as a result of these issues. Extensive surveillance after a recent outbreak found a low level (< 0.1%) of seropositive animals by ELISA. However, a re-analysis of these sera by immunoblotting suggests that they may be false positives.

Wildlife reservoirs are known to exist in Africa (zebras) and Mongolia (Przewalski's horses). Surveillance of wild or feral horses in many areas is limited.

Transmission

B. caballi and *T. equi* are transmitted by ticks, which act as biological vectors. Approximately 30 species of ticks in the genera *Dermacentor*, *Hyalomma*, *Haemaphysalis*, *Ixodes*, *Rhipicephalus* and *Amblyomma* have been implicated as natural or experimental vectors, although the epidemiological significance of some species is uncertain. *B. caballi* and *T. equi* can be transmitted transstadially in ticks, but transovarial transmission is only known to be significant for *B. caballi.* This species can be maintained in a tick population for several generations without reinfection from a vertebrate host. *B. caballi* and *T. equi* complete their maturation in the tick after it attaches to a host, and there is a delay before they are transmitted. These organisms can also be spread directly between animals by transfusions and blood-contaminated fomites such as reused needles. Transplacental transmission has been documented for both *T. equi* and *B. caballi*.

Horses, donkeys and other equids that become infected with *T. equi* and *B. caballi* can carry these organisms for long periods, with or without clinical signs. Carriers are not thought to eliminate *T. equi* without treatment, but how long *B. caballi* persists is unclear. Earlier reports indicated that horses clear this organism eventually, although they may remain carriers for several years; however, more sensitive techniques suggest that at least some horses may remain infected for life. Healthy carriers can include foals infected *in utero*.

Disinfection

Disinfection is not important in the control of equine piroplasmosis. If needed, an agent effective against protozoa should be selected.

Incubation Period

The incubation period for tick-transmitted acute illnesses is 12 to 19 days for *T. equi*, and 10 to 30 days for *B. caballi*. Clinical signs can be seen as quickly as 5-7 days when the organisms are inoculated directly into the blood.

Clinical Signs

Equids

The effects of equine piroplasmosis are variable, with some animals becoming infected without clinical signs and others developing acute or chronic illnesses.

In rare peracute clinical cases, animals may be found dead or dying. More often, acute cases in horses begin as a febrile illness, with nonspecific signs that may include inappetence, malaise, labored or rapid respiration, and congestion of the mucus membranes. Some cases can be mild and transient, but other animals become markedly ill. Most horses with acute piroplasmosis have some degree of anemia, which can result in pale or icteric mucous membranes, weakness and an increased heart rate and respiration. Hemoglobinuria or bilirubinuria may also be seen, and thrombocytopenia can result in petechiae on the mucous membranes, including those of the eye. Some animals have gastrointestinal signs such as colic, small and dry feces, or diarrhea. Edema of the limbs, a swollen abdomen from ascites, posterior weakness or swaying, and seizures may also be seen. Increased lacrimation, swelling of the eyelids and notably increased thirst are reported to be common in donkeys. Complications in severe cases can include kidney damage or acute renal failure, liver failure, disseminated intravascular coagulation, and secondary infections that can cause syndromes such as pneumonia.

Chronic piroplasmosis is usually a nonspecific illness with signs such as mild inappetence, poor exercise tolerance, weight loss and transient fevers. An enlarged spleen may be palpable on rectal examination. Anemia can be minimal or absent in chronically infected horses. Mild icterus and pale mucous membranes have been reported in some chronically infected donkeys.

Some infected horses, including asymptomatic carriers, may abort or give birth to stillborn foals. Live offspring born to these animals are sometimes weak at birth or appear normal but develop clinical signs after 2-3 days. While the initial signs may be nonspecific, the illness can quickly progress to anemia and severe jaundice. Some foals infected *in utero* have no clinical signs despite carrying the organism.

Other species

Some dogs found to be infected by PCR were asymptomatic or coinfected with other organisms; however, *T. equi* appeared to be responsible for anemia and thrombocytopenia in 2 dogs in South Africa. Clinical signs reported in dogs with theileriosis or babesiosis have included fever, pale mucous membranes, icterus, hematuria, hemoglobinuria, hematochezia, bleeding tendencies (petechiae, ecchymoses, oral bleeding) and splenomegaly. *T. equi* was found by PCR in a South American tapir with fever, lethargy and anemia; however, the animal had concurrent osteomyelitis after a fracture, and whether *T. equi* caused any of these signs was uncertain. As of 2018, no clinical signs have been attributed to *T. equi* or *B. caballi* in infected camels, but some authors suggest that they are probably pathogenic in some individuals.

Post Mortem Lesions

Click to view images

The gross lesions in acute illnesses may include evidence of anemia and icterus in the internal organs, hemorrhagic lesions (e.g., petechiae in the kidneys, subepicardial and subendocardial hemorrhages in the heart, ecchymoses) and an enlarged spleen. The liver is often enlarged and may be either dark orange-brown or pale from anemia. Additional lesions may include lymphadenopathy, discoloration and enlargement of the kidneys, pulmonary edema and congestion, hydropericardium, hydrothorax, ascites, edema, weight loss and signs related to secondary infections or complications.

Diagnostic Tests

Equine piroplasmosis can sometimes be diagnosed by detecting the organisms in blood or organ smears stained with Romanowsky-type stains such as Giemsa, Wright's or Diff-Quik®. Blood smears are optimally made from superficial skin capillaries during the acute phase of the disease. Thin films are usually used for parasite identification, but thick blood films can be helpful in detecting organisms present in low numbers. *B. caballi* typically appears as two large piriform merozoites joined at their posterior ends, while *T. equi* merozoites are relatively small, with a piriform, round or oval shape, and are sometimes connected in a tetrad known as a Maltese cross. *T. equi* can often be detected in the blood of acutely ill animals, but the number of *B. caballi* parasites tends to be lower. Both organisms are usually difficult or impossible to find in chronically infected animals.

Various PCR tests are available for *T. equi* and *B. caballi*, and are more sensitive than direct observation. However, *T. equi* is genetically variable and PCR tests developed to detect some isolates of this organism may miss others. A reverse line blot assay (RLB), multiplex PCR tests that can detect both organisms, and loop-mediated isothermal amplification (LAMP) assays have also been described.

Serological tests may be used to diagnose clinical cases and are also employed to detect asymptomatic carriers. The most commonly used tests are the indirect fluorescent antibody (IFA) assay and various ELISAs. Immunoblotting (Western blotting) is increasingly available in some countries. The complement fixation test is sometimes employed in clinical cases, but it has fallen out of favor as a screening test for carriers because the number of false negative tests was unacceptably high. Other tests, such as immunochromatographic assays, have also been described.

More labor intensive diagnostic methods may be necessary in some situations, for instance when evaluating whether treatment has eliminated the parasites from a carrier. Some of these techniques include *in vitro* culture, animal inoculation into an equid, and xenodiagnosis. In xenodiagnosis, pathogen-free ticks are fed on a suspect animal, and organisms are identified either in the ticks or in a susceptible mammal upon which the ticks are fed.

Treatment

Antiprotozoal drugs (e.g., imidocarb, diaminazene) are used to treat clinical cases in horses and donkeys. Tetracyclines have been used in animals infected with *T. equi*, but are reported to be ineffective against *B. caballi*. Zebras and dogs with clinical signs have also been treated successfully with imidocarb. Supportive care, such as transfusions, may be necessary in some animals.

Some recent reports suggest that certain protocols using imidocarb can clear *T. equi* and *B. caballi* from horses, including asymptomatic carriers. Other studies have found that these organisms usually persist in the body, although they may be suppressed for a time. Differences in the drug susceptibility of circulating strains might account for some conflicting results. If a treated animal is to remain in an equine piroplasmosis-free country, it must be thoroughly evaluated to ensure that the organism has been permanently cleared from the body. In the U.S., horses can only be treated in official programs under supervision by USDA APHIS.

Control

Disease reporting

Veterinarians who encounter or suspect an infection with *T. equi* or *B. caballi* should follow their national and/or local guidelines for disease reporting. In the U.S., state or federal authorities should be informed immediately.

Prevention

Carrier animals and infected ticks can introduce equine piroplasmosis into new regions. Piroplasmosis-free countries usually test equids for this disease during importation, using serological tests. Carriers are sometimes allowed to temporarily enter such countries for international competitions. In the U.S., these carriers are examined, treated for ticks, monitored as needed, and quarantined except when competing. Some events in the U.S. now require a negative test for equine piroplasmosis even if the animal resides within the country.

If an infected animal is discovered in a piroplasmosis-free region, it should be quarantined and kept from all contact with ticks. Options for its disposition may include permanent quarantine, export, euthanasia or treatment; the available options vary with the country. In recent years, the U.S. has allowed treatment under supervision, with post-treatment confirmation of clearance.

Tick bite prevention (e.g., the use of acaricides) may limit exposure in endemic regions. Frequent examination of the animal and the removal of ticks may eliminate some vectors before they can transmit the organism. Practices that can expose horses to blood from other equids, such as sharing needles, should be avoided, and blood donors used by veterinary hospitals should be negative for piroplasmosis. Illegal pre-race blood transfusions (blood doping) were implicated in some cases in the U.S. There is no vaccine for either *B. caballi* or *T. equi*.

Morbidity and Mortality

Asymptomatic infections with *B. caballi* and *T. equi* appear to be common in endemic regions. In some areas, equids tend to be exposed to these organisms when they are young and have some protection from maternal antibodies, and acute clinical cases are reported to be relatively infrequent. They are more likely to be seen when naive animals are introduced to an endemic region, or if an infected animal transmits the disease to equids in a piroplasmosis-free country. The mortality rate is influenced by the specific organism and the level of exposure, the host's health in general, and the availability of good veterinary care. The case fatality rate in horses is usually reported to be in the range of 5-10%, but rates of 50% or higher have been seen in some outbreaks, especially in naive horses. *T. equi* typically causes more severe clinical signs than *B. caballi*; however, some sources speculate that *T. equi* strains may differ in virulence, as the illnesses caused by this organism seem to be more severe in some countries than others. Relapses have been reported in infected horses after stressors or immunosuppression, including the use of corticosteroids.

There is limited information about the prevalence and significance of *T. equi* and *B. caballi* in feral or wild horses; however, this disease can have a significant impact on reintroduced populations of Przewalski's horses in Mongolia. Anecdotal reports suggest that piroplasmosis may cause fatalities of 20-25% in recently captured Grevy's zebras.

Internet Resources

The Merck Veterinary Manual
http://www.merckvetmanual.com/

United States Animal Health Association. Foreign Animal Diseases
http://www.aphis.usda.gov/emergency_response/downloads/nahems/fad.pdf

World Organization for Animal Health (OIE)
http://www.oie.int

OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals
http://www.oie.int/international-standard-setting/terrestrial-manual/access-online/

OIE Terrestrial Animal Health Code
http://www.oie.int/international-standard-setting/terrestrial-code/access-online/

Acknowledgements

This factsheet was written by Anna Rovid Spickler, DVM, PhD, Veterinary Specialist from the Center for Food Security and Public Health. The U.S. Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS) provided funding for this factsheet through a series of cooperative agreements related to the development of resources for initial accreditation training.

The following format can be used to cite this factsheet. Spickler, Anna Rovid. 2018. *Equine Piroplasmosis*. Retrieved from http://www.cfsph.iastate.edu/DiseaseInfo/factsheets.php.

References

Acha PN, Szyfres B (Pan American Health Organization [PAHO]). Zoonoses and communicable diseases common to man and animals. Volume 3. Parasitoses. 3rd ed. Washington DC: PAHO; 2003. Scientific and Technical Publication No. 580. Babesiosis; p.15-20.

Ali S, Sugimoto C, Onuma M. Equine piroplasmosis. J Equine Sci. 1996;7: 67-77.

Animal Health Australia. The National Animal Health Information System (NAHIS). Equine piroplasmosis [online]. Available at: http://www. aahc.com.au/nahis/disease/dislist.asp.* Accessed 3 Oct 2001.

Awinda PO, Mealey RH, Williams LB, Conrad PA, Packham AE, Reif KE, Grause JF, Pelzel-McCluskey AM, Chung C, Bastos RG, Kappmeyer LS, Howe DK, Ness SL, Knowles DP, Ueti MW. Serum antibodies from a subset of horses positive for *Babesia caballi* by competitive enzyme-linked immunosorbent assay demonstrate a protein recognition pattern that is not consistent with infection. Clin Vaccine Immunol. 2013;20(11):1752-7.

Bahrami S, Tabandeh MR, Tafreshi ARG. Prevalence and molecular identification of piroplasmids in Iranian dromedaries (*Camelus dromedarius*). Zoo Wildl Med. 2017;48(4):1026-30.

Barros CSL. Babesiosis. In: Foreign animal diseases. 7th edition. Boca Raton, FL: United States Animal Health Association; 2008.p.147-57.

Beaver PC, Jung RC, Cupp EW. Clinical parasitology. 9th ed. Philadelphia: Lea & Febiger; 1984. Family Babesiidae; p. 205-12.

Beck R, Vojta L, Mrljak V, Marinculić A, Beck A, Zivicnjak T, Cacciò SM. Diversity of *Babesia* and *Theileria* species in symptomatic and asymptomatic dogs in Croatia. Int J Parasitol. 2009;39(7):843-8.

Bhoora R, Buss P, Guthrie AJ, Penzhorn BL, Collins NE. Genetic diversity of piroplasms in plains zebra (*Equus quagga burchellii*) and Cape mountain zebra (*Equus zebra zebra*) in South Africa. Vet Parasitol. 2010;174(1-2):145-9.

Bhoora RV, Pienaar R, Cornelius F, Josemans A, Matthee O, Marumo R, Troskie C, Mans BJ. Multiplex hydrolysis-probe assay for the simultaneous detection of *Theileria equi* and *Babesia caballi* infections in equids. Vet Parasitol. 2018;255:61-8.

Bowhill T. Equine piroplasmosis, or "biliary fever." J Hyg (Lond). 1905;5: 7-17.

Brooks L, Cordes T, Knowles D, Stiller D. Piroplasmosis of horses: What is known concerning transmission and disease risk? J Equine Vet Sci. 1996; 16:184-8.

Bruning E. Equine piroplasmosis. An update on diagnosis, treatment, and prevention. Br Vet J. 1996;152:139-51.

Butler C. Can *Theileria equi* be eliminated from carrier horses? Vet J. 2013;196(3):279.

Butler CM, Nijhof AM, van der Kolk JH, de Haseth OB, Taoufik A, Jongejan F, Houwers DJ. Repeated high dose imidocarb dipropionate treatment did not eliminate *Babesia caballi* from naturally infected horses as determined by PCR-reverse line blot hybridization. Vet Parasitol. 2008;151:320-2.

Butler CM, Sloet van Oldruitenborgh-Oosterbaan MM, Stout TA, van der Kolk JH, Wollenberg Lv, Nielen M, Jongejan F, Werners AH, Houwers DJ. Prevalence of the causative agents of equine piroplasmosis in the south west of The Netherlands and the identification of two autochthonous clinical *Theileria equi* infections. Vet J. 2012;193(2):381-5.

Coultous RM, Phipps P, Dalley C, Lewis J, Hammond TA, Shiels BR, Weir W, Sutton DGM. Equine piroplasmosis status in the UK: an assessment of laboratory diagnostic submissions and techniques. Vet Rec. 2018 Nov 9. pii: vetrec-2018-104855.

Criado A, Martinez J, Buling A, Barba JC, Merino S, Jefferies R, Irwin PJ. New data on epizootiology and genetics of piroplasms based on sequences of small ribosomal subunit and cytochrome b genes. Vet Parasitol 2006;142:238-47.

Criado-Fornelio A, Martinez-Marcos A, Buling-Sarana A, Barba-Carretero JC. Molecular studies on *Babesia*, *Theileria* and *Hepatozoon* in southern Europe. Part I. Epizootiological aspects. Vet Parasitol. 2003; 13: 189-201.

Da Silveira AW, De Oliveira GG, Menezes Santos L, da Silva Azuaga LB, Macedo Coutinho CR, Echeverria JT, Antunes TR, do Nascimento Ramos CA, Izabel de Souza A. Natural infection of the South American tapir (*Tapirus terrestris*) by *Theileria equi*. J Wildl Dis. 2017;53(2):411-3.

de Sousa KCM, Fernandes MP, Herrera HM, Freschi CR, Machado RZ, André MR. Diversity of piroplasmids among wild and domestic mammals and ectoparasites in Pantanal wetland, Brazil. Ticks Tick Borne Dis. 2018;9(2):245-53.

Florida Department of Agriculture and Consumer Services, Division of Animal Industry [FDACS]. Equine piroplasmosis update [online].FDACS; 2008 Aug. Available at: http://www.doacs.state.fl.us/ai/pdf/Equine_Piroplasmosis_Situation_Web_Update.pdf.* Accessed 28 Aug 2008.

Fritz D. A PCR study of piroplasms in 166 dogs and 111 horses in France (March 2006 to March 2008). Parasitol Res. 2010;106(6):1339-42.

Gabrielli S, Otašević S, Ignjatović A, Savić S, Fraulo M, Arsić-Arsenijević V, Momčilović S, Cancrini G. Canine babesioses in noninvestigated areas of Serbia. Vector Borne Zoonotic Dis. 2015;15(9):535-8.

Githaka N, Konnai S, Bishop R, Odongo D, Lekolool I, Kariuki E, Gakuya F, Kamau L, Isezaki M, Murata S, Ohashi K. Identification and sequence characterization of novel *Theileria* genotypes from the waterbuck (*Kobus defassa*) in a *Theileria parva*-endemic area in Kenya. Vet Parasitol. 2014;202(3-4):180-93.

Grause JF, Ueti MW, Nelson JT, Knowles DP, Kappmeyer LS, Bunn TO. Efficacy of imidocarb dipropionate in eliminating *Theileria equi* from experimentally infected horses. Vet J. 2013;196(3):541-6.

Hawkins E, Kock R, McKeever D, Gakuya F, Musyoki C, Chege SM, Mutinda M, Kariuki E, Davidson Z, Low B, Skilton RA, Njahira MN, Wamalwa M, Maina E. Prevalence of *Theileria equi* and *Babesia caballi* as well as the identification of associated ticks in sympatric Grevy's zebras (*Equus grevyi*) and donkeys (*Equus africanus asinus*) in northern Kenya. J Wildl Dis. 2015;51(1):137-47.

Hines SA, Ramsay JD, Kappmeyer LS, Lau AO, Ojo KK, Van Voorhis WC, Knowles DP, Mealey RH. *Theileria equi* isolates vary in susceptibility to imidocarb dipropionate but demonstrate uniform in vitro susceptibility to a bumped kinase inhibitor. Parasit Vectors. 2015;8:33.

Holman PJ, Hietala SK, Kayashima LR, Olson D, Waghela SD, Wagner GG. Case report: field-acquired subclinical *Babesia equi* infection confirmed by i*n vitro* culture. J Clin Microbiol. 1997;35:474-6.

Hunfeld KP, Brade V. Zoonotic *Babesia*: possibly emerging pathogens to be considered for tick-infested humans in Central Europe. Int J Med Microbiol. 2004;293 Suppl 37:93-103.

Knowles DP, Kappmeyer LS, Haney D, Herndon DR, Fry LM, et al. Discovery of a novel species, *Theileria haneyi* n. sp., infective to equids, highlights exceptional genomic diversity within the genus *Theileria*: implications for apicomplexan parasite surveillance. Int J Parasitol. 2018;48(9-10):679-90.

Kumar S, Kumar R, Sugimoto C. A perspective on *Theileria equi* infections in donkeys. Jpn J Vet Res. 2009;56(4):171-80.

Lampen F, Bhoora R, Collins NE, Penzhorn BL. Putative clinical piroplasmosis in a Burchell's zebra (*Equus quagga burchelli*). J S Afr Vet Assoc. 2009;80(4):257-60.

Laus F, Spaterna A, Faillace V, Veronesi F, Ravagnan S, Beribé F, Cerquetella M, Meligrana M, Tesei B. Clinical investigation on *Theileria equi* and *Babesia caballi* infections in Italian donkeys. BMC Vet Res. 2015;11:100.

Levine ND. Veterinary protozoology. Ames, IA: Iowa State University Press; 1985. p 414.

Lobanov VA, Peckle M, Massard CL, Brad Scandrett W, Gajadhar AA. Development and validation of a duplex real-time PCR assay for the diagnosis of equine piroplasmosis. Parasit Vectors. 2018;11(1):125.

Mans BJ, Pienaar R, Latif AA. A review of *Theileria* diagnostics and epidemiology. Int J Parasitol Parasites Wildl. 2015;4(1):104-18.

Ogunremi O, Halbert G, Mainar-Jaime R, Benjamin J, Pfister K, Lopez-Rebollar L, Georgiadis MP. Accuracy of an indirect fluorescent-antibody test and of a complement-fixation test for the diagnosis of *Babesia caballi* in field samples from horses. Prev Vet Med. 2008;83:41-51.

Piantedosi D, D'Alessio N, Di Loria A, Di Prisco F, Mariani U, Neola B, Santoro M, Montagnaro S, Capelli G, Veneziano V. Seroprevalence and risk factors associated with *Babesia caballi* and *Theileria equi* infections in donkeys from Southern Italy. Vet J. 2014;202(3):578-82.

Qablan MA, Kubelová M, Siroký P, Modrý D, Amr ZS. Stray dogs of northern Jordan as reservoirs of ticks and tick-borne hemopathogens.Parasitol Res. 2012;111(1):301-7.

Qablan MA, Sloboda M, Jirků M, Oborník M, Dwairi S, Amr ZS, Hořín P, Lukeš J, Modrý D. Quest for the piroplasms in camels: identification of *Theileria equi* and *Babesia caballi* in Jordanian dromedaries by PCR. Vet Parasitol. 2012;186(3-4):456-60.

Rosa CT, Pazzi P, Nagel S, McClure V, Christie J, Troskie M, Dvir E. Theileriosis in six dogs in South Africa and its potential clinical significance. J S Afr Vet Assoc. 2014;85(1):1114.

Sant C, d'Abadie R, Pargass I, Basu AK, Asgarali Z, Charles RA, Georges KC. Prospective study investigating transplacental transmission of equine piroplasmosis in thoroughbred foals in Trinidad. Vet Parasitol. 2016;226:132-7.

Schwint ON, Ueti MW, Palmer GH, Kappmeyer LS, Hines MT, Cordes RT, Knowles DP, Scoles GA. Imidocarb dipropionate clears persistent *Babesia caballi* infection with elimination of transmission potential. Antimicrob Agents Chemother. 2009;53(10):4327-32.

Scoles GA, Ueti MW. Vector ecology of equine piroplasmosis. Annu Rev Entomol. 2015;60:561-80.

Solano-Gallego L, Baneth G. Babesiosis in dogs and cats - expanding parasitological and clinical spectra. Vet Parasitol. 2011;181:48-60.

Tarav M, Tokunaga M, Kondo T, Kato-Mori Y, Hoshino B, Dorj U, Hagiwara K. Problems in the protection of reintroduced Przewalski's horses (*Equus ferus przewalskii*) caused by piroplasmosis. J Wildl Dis. 2017;53(4):911-5.

Ueti MW, Mealey RH, Kappmeyer LS, White SN, Kumpula-McWhirter N, Pelzel AM, Grause JF, Bunn TO, Schwartz A, Traub-Dargatz JL, Hendrickson A, Espy B, Guthrie AJ, Fowler WK, Knowles DP. Re-emergence of the apicomplexan *Theileria equi* in the United States: elimination of persistent infection and transmission risk. PLoS One. 2012;7(9):e44713.

Ueti MW, Palmer GH, Scoles GA, Kappmeyer LS, Knowles DP. Persistently infected horses are reservoirs for intrastadial tick-borne transmission of the apicomplexan parasite *Babesia equi*. Infect Immun. 2008;76:3525-9.

Uilenberg G. *Babesia*--a historical overview. Vet Parasitol. 2006;138:3-10.

United States Animal Health Association [USAHA]. Committee on Infectious Diseases of Horses. Resolution No. 9: Equine piroplasmosis [online]. USAHA; 2006 Oct. Available at: http://www.usaha.org/committees/resolutions/2006/resolution09-2006.pdf.* Accessed 29 Aug 2008.

United States Department of Agriculture. Animal and Plant Health Inspection Service [USDA APHIS]. Equine piroplasmosis and the 1996 Atlanta Olympic Games [online]. USDA APHIS; 1995 Dec. Available at: http://www.aphis.usda.gov/oa/pubs/fsepiro.html.* Accessed 17 Oct 2001.

Vroege C, Zwart P. Babesiasis in a Malayan tapir (*Tapirus indicus* Desmarest, 1819). Z Parasitenkd. 1972;40:177-9.

Wise LN, Kappmeyer LS, Mealey RH, Knowles DP. Review of equine piroplasmosis. J Vet Intern Med. 2013;27(6):1334-46.

Wise LN, Kappmeyer LS, Silva MG, White SN, Grause JF, Knowles DP. Verification of post-chemotherapeutic clearance of *Theileria equi* through concordance of nested PCR and immunoblot. Ticks Tick Borne Dis. 2018;9(2):135-40.

Wise LN, Pelzel-McCluskey AM, Mealey RH, Knowles DP. Equine piroplasmosis. Vet Clin North Am Equine Pract. 2014;30(3):677-93.

World Organization for Animal Health [OIE]. Manual of diagnostic tests and vaccines for terrestrial animals [online]. Paris: OIE; 2018. Equine piroplasmosis. Available at: http://www.oie.int/fileadmin/Home/eng/Health_standards/tahm/2.05.08_EQUINE_PIROPLASMOSIS.pdf. Accessed 28 Nov 2018.

World Organization for Animal Health (OIE). World animal health information database (WAHIS) interface. Equine piroplasmosis. Paris:OIE;2018. Available at: http://www.oie.int/wahis_2/public/wahid.php/Diseaseinformation/statuslist. Accessed 28 Nov 2018.

Zanet S, Bassano M, Trisciuoglio A, Taricco I, Ferroglio E. Horses infected by piroplasms different from *Babesia caballi* and *Theileria equi*: species identification and risk factors analysis in Italy. Vet Parasitol. 2017;236:38-41.

Zobba R, Ardu M, Niccolini S, Chessa B, Manna L, Cocco R, Parpagliae MLP. Clinical and laboratory findings in equine piroplasmosis. J Equine Vet Sci. 2008; 28: 301-8.

*Link is defunct