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Review Article

TICK-BORNE ZOONOTIC DISEASES AND ITS CONTROL

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ABSTRACT

The present review article explains different zoonotic diseases transmitted by various species of ticks. This article emphasizes various animal hosts, transmission and prevalence of various zoonotic diseases caused by a virus, bacteria, protozoans in different eco-climatic regions of the world. This article also explains various diagnostic methods applied for the detection of disease pathogens, treatment methods and prophylactic measures. It recommends tick saliva antigen-based oral vaccines and antibiotics as treatment methods. It also suggests use of various bait formulations and cultural control methods for deterring ticks from blood feeding. This article signifies the need of pesticides for control of ticks and tick-borne diseases.

Keywords: Ticks, Zoonotic diseases, Pathogens, Control methods, Biopesticides, Powassan encephalitis

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INTRODUCTION

Ticks are implicated in the transmission of a number of infectious diseases caused by various groups of pathogens such as bacteria, viruses, and protozoa. Ticks spread infectious diseases such as *Lyme borreliosis, ehrlichiosis, anaplasmosis* and *babesiosis.* In the last four decades due to the movement of human population, domestic and wild animals, trade and traffic ticks are arriving into new endemic regions of the world. Exposure of tick-borne pathogens is increasing in geographic ranges that are resulting in heavy morbidity and mortality. Ticks-borne disease severely affecting human health and are more dangerous than envenomation [1]. Few tick species such as *Hyalomma* and *Ixodes ricinus, Ixodes scapularis, Amblyomma americanum, Dermacentor variabilis* infect large number of vertebrate hosts, including migratory birds. Many of these are responsible for the spread of spotted fever caused by *Rickettsia* species [2] (table 1). *Borrelia burgdorferi* infection is common in horses, while *Borrelia miyamotoi* in humans [3]. There is an alarming situation as few TBDs such as Lyme disease is, expanding endemic areas of the new geographic range due to increased anthropogenic activities, migration of birds and animal trade [3].

Source of information

For writing this comprehensive research review on tick-borne diseases, various databases *were searched*. For the collection of relevant information specific terms such as medical subject headings (MeSH) and key text words, such as "disease pathogens", "transmission by ticks" published till 2022 were used in MEDLINE. Most especially for retrieving all articles pertaining to the use of tick-borne diseases and its control, electronic bibliographic databases *was searched* and abstracts of published studies with relevant information on the tick-borne diseases were collected. Furthermore, additional references were included through searching the references cited by the studies done on the present topic. Relevant terms were used individually and in combination to ensure an extensive literature s*earch.* For updating the information about a subject and incorporation of recent knowledge, relevant research articles, books, conferences proceedings and public health organization survey reports were selected and collated based on the broader objective of the review. This was achieved by searching databases, including SCOPUS, Web of Science, and EMBASE, Pubmed, PMC, Publon, Swissprot, Google searches" From this common methodology, discoveries and findings were identified and summarized in this final review.

Tick hosts and transmission

Ticks are currently considered to be second only to mosquitoes as vectors of human infectious diseases in the world. Ticks are highly active small-sized vectors which parasites pets like dogs and cats and spread series of zoonotic diseases. There is a range of vertebrate hosts such as sheep, cows and horses [4] and several ungulate species which are used by ticks feeding and propagation hosts. Free-living ungulates are hosts of ixodid ticks and reservoirs of tick-borne microorganisms in central Europe and many regions around the world [5]. Ungulates are amplifying and dilution hosts, of two important pathogens *Anaplasma phagocytophilum* and *Borrelia burgdorferi* [6] (table 1). The incidence of zoonotic diseases is massively increased due to the presence of various hosts and suitable environmental conditions. All these factors help in establishment of tick population as large number of animal hosts are easily available and ticks un-interrupted get blood feeding for a long time.

It also determines the geographic distribution of the ticks and, consequently, become the risk areas for tick-borne diseases. This is particularly the case when ticks are vectors and reservoirs of the pathogens. *Ixodes ricinus* tick acts both as a vector and reservoir for a series of wildlife. *A. Phagocytophilum* and *Theileria spp.* are spread bandaged ixodid ticks remain attached to the skin of ungulates [5]. Some of these diseases are inflicted bites, scratches or licking. Some systemic infectious and parasitic diseases are transmitted from animals to humans and vice versa. Such a situation may lead to endemic problems in some communities [7]. Ticks and tick-borne pathogens found in multiple land-use types that are responsible for the easy transmission of disease pathogens [8]. The tick Immunobiology plays a significant role in establishing and transmitting many pathogens to their hosts [9] *Hyalomma* ticks on migratory birds [10]. Tick-borne diseases are also spread by companion animals like dogs and cats transported by humans (table 2). The risk of transmission of pathogen-infected ticks has increased substantially in recent decades due to the rise in tourist and economic migration rates.

The brown dog tick *Rhipicephalus sanguineus,* which is a vector of numerous pathogens causing diseases in animals and humans, is imported most frequently to many European countries from endemic areas in the Mediterranean region or from other parts of the world [11]. This spread of tick-borne viruses also increased in the last decade due to human movements and agricultural, tourism, trade and commerce. Besides this, environmental conditions also support the expansion of tick populations [12] (table 1). Although global warming is often cited as the underlying mechanism favoring the spread of tick-borne diseases, the climate has been just one of many factors that determine which tick species are found in a given geographic region.

Table 1: Important virus diseases transmitted by various tick species

S. No.	Disease	Organism	Vector	Geographical distribution	Symptom	Treatment	References
1	Eyach virus disease	Eyach virus (*Ixodes ricinus*)	Africa Central Asia Southern Europe	Rare	Biphasic fever, chills, headache, generalized musculoskeletal aches, and malaise.	Preventative measures include tick and mosquito repellents such as diethyltoluamide, physical barriers, and reduction of standing water.	[1]
2	Tick borne encephalitis	TBE virus complex *Ixodes ricinus, Ixodes persulcatus*	Europe Asia, Middle East	Common and widespread	Swelling of the brain and/or spinal cord, confusion, and sensory disturbances	no specific drug therapy for TBE	[14]
3	Crimean–Congohemorrhagic fever (CCHF)	(CCHF) virus (Hyalomma marginatum)other tick species	Europe Central Asia, India, Africa	Common and widespread increasing	Headache, high fever, back pain, joint pain, stomach pain, and vomiting.	Maintain fluid balance and correction of electrolyte abnormalities, oxygenation and hemodynamic support,	[27]
4	Powassan encephalitis	POW virus *(Ixodes scapularis, Ixodes cookie)*	Northern US/adjacent Canada far eastern Russia	Rare increasing	Swelling of the membranes surrounding the brain and spinal cord	No medication to treat Powassan virus infection.	[32]
5	Severe fever with thrombocytopenia syndrome (SFTS)	SFTS virus *(Haemophysalis longicornis, Rhipicephalus microplus*	China Korea Japan	Uncommon increasing	Thrombocytopenia, leukopenia, nausea, and vomiting	No prospective randomized studies on treatment strategies	
6	Other TBEs Omsk hemorrhagic fever (OHF), Kyasanur Forest Disease(KFD) Louping ill virus, others	OHF virus KFD Louping ill virus (Ixodes Dermacentor, Haemophysalis)	Europe, Russia, China, Japan, India, Southeast Asia, Middle East	Rare to common within localized range some increasing	High-grade fever with chills, intense frontal headache, severe myalgia and body aches	no treatment	[32]
7	Heartland virus disease	Heartland virus (Amblyamma americanum)	Midwestern and Southwestern US	Rare	Fever, fatigue (feeling tired), decreased appetite, headache, nausea, diarrhea, and muscle or joint pain	No vaccines or medications to prevent or treat infection	[32]
8	Colorado tick fever	*CTF virus*	*D. andersoni*	?	Photophobia, vomiting, meningoencephalitis, and slight or partial paralysis.	no specific treatment for Colorado tick fever (CTF)	[32]
9	Meningoencephalitis	TBEV (FSME) virus,flavivirus	Deer tick(*Ixodes persulcatus*), *Ixodes ricinus* (Europe), *Ixodespersulcatus*	Europe and northern Asia	Meningitis	Supervision, bed rest, and other measures are important to prevent worsening symptoms	[32]
10	LSD (Lumpy skin disease)	LSD Virus	Cattle	?	Skin nodules and oedema, enlarged lymph nodes, nasal discharge	no treatment	[48]
11	Thogotovirus (THOV) disease, Dhori virus (DHOV)disease Bourborn virus disease	(THOV) (DHOV)disease Bourborn virus *(Hyalommma, Amblyomma, Rhipicephalus)*	Africa, Asia Europe, (THOV) (DHOV) USA, (Bourborn)	Rare, Bourborn virus isolated from Amblomma americanum	Meningitis and neuromyelitis optica	No specific treatment or vaccine	
12	Bhanja virus disease	*Dermacentor, Haemophysalis*	Africa Central Asia Southern Europe	Rare	Fever, fatigue, pain	Acetaminophen	[88]

Table 2: Important bacterial diseases transmitted by various tick species

S. No.	Disease	Organism	Vector	Geographical distribution	Symptom	Treatment	Refrences
1	Lyme borreoliosis disease	*Borrelia burgodorferi*	*Ixodes scapularis Ixodes pacificus Ixodes ricinus*	North east, Midwest and west coast states, Europe, south-central U. S.	Erythema migrans, Fatigue, erythema migrans, malaisemyalgias, arthralgias, headache, fever chills	Amoxicillin) or cefuroxime Doxycycline (Vibramycin, non-steroidal anti-inflammatory drugs	[1]
2	Cowdriosis	*Cowdria ruminant ium*	*Amblyoma varieg atum*	Sub-saharan Africa	increased vascular permeability due to vascular endothelial cell invasion and consequent oedema and hypovolaemia: hyperaesthesia, aggression,	Sulphonamides and tetracyclines	[1]
3	Anaplasmosis	*Anaplasma phago cytophilum*	*Ixodes scapularis Ixodes pacificus*	North east, Midwest and west coast states	Myalgias, headache, fever chills	Doxycycline Chloramphenicol (Chloromycetin) Rifampin (Rifadin)	[1]
4	Anaplasmosis	*Anaplasma platys*	*Rhipicephalus sanguineus*	South central south western, U. S.	Myalgias,, headache, fever chills	Doxycycline Chloramphenicol Chloromycetin) Rifampin (Rifadin)	[1]
5	Southern rash illness	*Borrelia*	*A. americanum*	*southern* states and along the Atlantic coast as far north as Maine	Fever, headache, stiff neck, and mild muscle or joint pain.	(doxycycline)	[2]
6	Lyme disease	*Borrelia*	*I. scapularis, I. pacificus*	Northeastern United States. The upper Midwest	Fever, headache, chills, muscle and joint pain, fatigue	Amoxicillin, cefuro xime, and doxycycline.	[3]
7	Tick-borne Relapsing Fever	*Borrelia species*	*Ornithodoros species ticks*	Canada and Mexico United States,	Muscle pain, high fever, Headache, chills, vomiting and stomach pain	Doxycycline, Tetracyclin, erythromycin	[6]
8	Tick paralysis	*Toxin*	*D. variabilis, D. andersoni*	Argentina, Canada, and in several regions of the United States.	Muscle pain and feel tired and irritable	DEET, picaridin, IR3535, oil of lemon, eucalyptus, para-menthane-diol, or 2-undecanon	[26]
9	Ehrlichiosis	*Ehrlichiacanis*	*Rhipicephalus san guineus*	South central south western, U. S	Myalgias,headache, fever chills	Doxycycline Chloramphenicol (Chloromycetin) Rifampin (Rifadin)	[32]
10	Ehrlichiosis	*Ehrlichia ewingii, Ehrlichia,chaffeen sispanola mountain Ehrlichia, sp*	*Amblyomma americanum*	Cental and southeastern U. S. Extending northward along the atlantic coast	Myalgias, headache, fever chills	Doxycycline Chloramphenicol (Chloromycetin) Rifampin (Rifadin)	[32]
11	Ehrlichiosis	*Ehrlichia muris*	*Ixodes scapularis*	Upper Midwest (minnesota and Wisconsin)	Myalgias, headache,fever chills	Chloramphenicol Rifampin (Rifadin) (Chloromycetin)	[32]
12	Nairobi sheep disease	*Bunyaviridae*	*Rhipicephalus appendiculatus*	East and Central Africa Botswana and Mozambique. As ia, including India and Sri Lanka	Depression, anorexia, mucopurulent to hemorrhagic nasal discharge, occasional conjunctivitis, and fetid dysentery that causes painful straining.	no specific treatment,	[42]
13	Theileriosis	*Theileria annulata, T. parva, T. hirci*	*H. anatolicum, R. appenticulatus*	North Africa, southern Europe, the Near and Middle East, India	ever, swollen peripheral lymph nodes, pallour of mucous membranes, anaemia, nasal discharge, jaundice, salivation, rapid and shallow breathing, watery eyes	Tetracycline, buparvaquone	[45]
14	Babesiosis	*B. equi*	*H. anatolicum*	United States, Northeast and	Fever, chills, sweats. Malaise, fatigue.	diminazene imidoc arb	[45]

S. No.	Disease	Organism	Vector	Geographical distribution	Symptom	Treatment	Refrences
				Midwest, Washington and California	Myalgia, arthralgia, headache. Gastrointestinal symptoms, such as anorexia and nausea (less common: abdominal pain, vomiting) Dark urine	azithromycin atov aquone clindamycin	
15	African swine fever	*African swine fever virus*	*Ornithodorus mobuta*	Africa, Italian island of Sardinia. Belgium, Bulgaria, Lithuania, Poland and Romania.	• High fever. • Decreased appetite and weakness. • Red/blotchy skin lesions. • Diarrhea, vomiting. • Coughing. • Difficulty breathing.	No treatment or effective vaccine exists	[47]
16	Rocky mountain spotted fever	*Rickettsia ricketsii*	*Dermacentor variabilis Rhipicephalus sanguineus, D. andersoni*	Southcentral and southwestern and eastern U. S.	Myalgias,, headache, fever, malaise, vomiting, rash	Chloramphenicol tetracyclin Doxycycline	[47]
17	Tularemia	*Francisella tularensis*	*Ixodes scapularis Amblyomma americanum Dermacentor variabilis*	South and Midwest	Myalgias, headache, fever, chills, vomiting, fatigue, sore throat, abdominal pain, skin ulcers, diarrhea, S lymphadenopathy	Chloramphenicol Streptomycin Gentamicin,Tetrac yclin, Fluroquinolones	[52]
18	Babesiosis	*B. bigemina, B. ovis*	*R. (B.) microplus.*	United States, Northeast and Midwest, Washington and California	Fever, chills, sweats. Malaise, fatigue. Myalgia, arthralgia, headache. Gastrointestinal symptoms, such as anorexia and nausea (less common: abdominal pain, vomiting) Dark urine.	diminazene imidoc arb azithromycin atov aquone clindamycin	[58]
19	Babesiosis	*B. motasi*	*Haemaphysalis spp*	United States, Northeast and Midwest, Washington and California	Fever, chills, sweats. Malaise, fatigue. Myalgia, arthralgia, headache. Gastrointestinal symptoms, such as anorexia and nausea (less common: abdominal pain, vomiting) Dark urine	diminazene imidoc arb azithromycin atov aquone clindamycin	[58]
20	Human Babesiosis	*B. divergens*	*Ixodes spp.*	United States, Northeast and Midwest, Washington and California	Fever, chills, headache, nausea, vomiting, and/or muscle aches (myalgia).	Atovaquone plus azithromycin clindamycin plus quinine.	[58]
21	African horse sickness	*Reoviridae (African horse sickness virus)*	*Hyalomma dromedarii*	Sub-Saharan Africa, Morocco, the Middle East, India, and Pakistan Iberian Peninsula and T hailand	Respiratory failure high fever, depression, and respiratory symptoms pulmonary edema, conjunctivitis dyspnea	No treatment or effective vaccine exists	[82]

Tick-borne virus encephalitis (TBE) a flavivirus [14] is the most important viral tick-borne live inside large number of wild and domestic animals [15]. TBE virus circulates in a complex cycle involving small mammals as amplifying hosts and ticks as vectors and reservoirs [16] These transmit pathogens include *Anaplasma spp., Bartonella spp., Burkholderia spp., Francisella spp.*, Dera Ghazi Khan virus (DGKV), tick-borne encephalitis virus (TBEV), Lake Clarendon virus (LCV), Saumarez Reef virus (SREV), Upolu virus (UPOV), or Vinegar Hill virus (VINHV) (table 2). Humans can become infected by a tick bite and in some cases also by consumption of non-pasteurized raw milk and raw milk products from ruminants [18]. The local host skin site of tick attachment, modulated by tick saliva, is an important focus of virus replication. Immunomodulation of the tick attachment site also promotes the co-feeding transmission of viruses from infected to non-infected ticks in the absence of host viraemia [19]. Most tick-borne viruses (TBV) are RNA viruses, some of which cause serious diseases in humans and animals worldwide [19]. Some of these viruses show non-viraemic transmission [19]. Ticks serve as important vectors of a variety of pathogens, mainly viral and prokaryotic. Vector competence is a component of bacterial capacity and depends on genetic determinants affecting the ability of a vector to transmit a pathogen. These determinants affect traits such as tick-host-pathogen and susceptibility to pathogen infection. Therefore, the elucidation of the mechanisms involved in tick-pathogen interactions that affect vector competence is essential for the identification of molecular drivers for tick-borne diseases [20].

Blacklegged tick*, Ixodes scapularis* is a major vector that transmits Lyme disease *(Borrelia burgdorferi),* human granulocytic *anaplasmosis (Anaplasma phagocytophilum),* and *babesiosis (Babesia microti)* [21]. Several human pathogens are transmitted by the *blacklegged tick, Ixodes scapularis.* These include the spirochetes [22]. *Ixodes scapularis* is currently known to transmit 7 pathogens responsible for Lyme disease, *anaplasmosis, babesiosis, tick-borne relapsing fever, ehrlichiosis,* and *Powassan encephalitis. Ixodes scapularis* can also be colonized by endosymbiotic bacteria, including those in the genus *Rickettsia*. *Ixodes scapularis* female nymphs are highly infective (table 2). High prevalence of infection and co-infection with multiple pathogens in *Ixodes scapularis* increased the public health consequences in an endemic area [23].

Viral diseases

Ticks transmit several human virus diseases in different eco-climatic zones of the world. A large diversity of ticks is detected from European, African and Asian countries. Among them are flaviviruses which are medically most important arboviruses reported from Europe and Asia. These causes between 10,000 and 15,000 human deaths annually in European countries alone [24] From European countries 6 medically important families are Flaviviridae, Bunyaviridae, and Reoviridae. In addition, three genera, flavivirus, nairovirus, and orbivirus, are the most prevalent [25]. Two new clouds of tick-borne phleboviruses, a mononega virus are also reported in *Ixodes scapularis* [26]. Among important diseases causing viruses are Flavivirus, tick-borne encephalitis virus, Omsk hemorrhagic fever virus, louping ill virus, Powassan virus, Nairovirus (Crimean-Congo hemorrhagic fever virus) and Coltivirus (each virus), which cause neurological diseases, hemorrhagic fever [27]. Most of the viruses are characterized from three species of ticks *Amblyomma americanum*, *Dermacentor variabilis,* and *Ixodes scapularis* [26]. *Rhipicephalus microplus* ticks contain huge virome diversity which is identified and reported from Hubei Province of China. Twelve RNA viruses with complete genomes were identified, which belonged to six viral families: Flaviviridae, Matonaviridae, Peribunyaviridae, Nairoviridae, Phenuiviridae, and [28]. Ticks transmitted by novel RNA viruses are also reported from Australia. Notably, three of these viruses clustered with known mammalian viruses, including novel cultivars that were related to the human pathogen Colorado tick fever virus [29] (table 2).

Tick-borne encephalitis

Ticks are important vectors for the transmission of pathogens, including viruses. Tick-borne encephalitis virus (TBEV) and Omsk hemorrhagic fever virus (OHFV) are highly pathogenic tick-borne flaviviruses. These are the leading cause of encephalitis that is an emerging disease spreading in many regions of Eurasia in dogs. Dogs become readily infected with the TBE virus, but they are accidental hosts not capable to further spread the virus. TBEV causes neurological disease in humans, while OHFV causes a disease typically identified with hemorrhagic fever [30].

Tick also harbors endogenous viruses and modulation of tick-borne pathogen growth. The viruses carried by tick's also known as tick-borne viruses (TBVs), contain a large group of viruses with diverse genetic properties and are concluded in two orders, nine families, and at least 12 genera. Tick-borne encephalitis virus (TBEV) is a major arbovirus that causes thousands of cases of severe neurological illness in humans annually [31]. Ticks also transmit Powassan virus; a neurovirulent flavivirus that causes meningoencephalitis in North America and eastern Russia. Powassan virus disease displays severe neurological symptoms [32]. The main vectors of Powassan virus are *Ixodes cookei*, *Ix. scapularis*, *Ix. marxi, Ix. spinipalpusm*, *Dermacentor andersoni*, and *D. variabilis.* Ticks are efficient vectors of arboviruses, although less than 10% of tick species are known to be virus vectors. Ticks transmit viruses of flaviviridae virus family, mainly Kyasanur Forest Disease Virus (KFDV). Ticks transmit viruses of the flaviviridae virus family, mainly Kyasanur Forest Disease Virus (KFDV) (table 3). Ticks also transmit Tick-borne meningoencephalitis virus, a flavivirus spread by deer ticks *(Ixodes scapularis), Ixodes ricinus* (Europe), *Ixodes persulcatus* in Russia and Asia. This virus is endemic in Europe and northern Asia. Ticks also spread Colorado tick fever that is caused by Colorado tick fever virus (CTF), a coltivirus from the Reoviridae. Its transmission vector is *Dermacentor andersoni* in Western America. Crimean-Congo hemorrhagic fever is caused by CCHF virus, a nairovirus, from the Bunyaviridae and transmitted by *Hyalomma marginatum*, *Rhipicephalus bursain* Southern part of Asia, Northern Africa, and Southern Europe. Severe febrile illness is caused by Heartland virus, a phlebovirus, from the Bunyaviridae by Lone star tick *(Amblyomma americanum)* found in Missouri and Tennessee United States (table 3).

Table 3: Important protozoan diseases transmitted by various tick species

S. No.	Disease	Organism	Vector	Symptom	Treatment	References
1	Babeiosis	*Babesia vogal*	*Rhipicephalus sanguineus*	Severe headache, nausea, abdominal pain, hemolytic anemia, fever, chills, sweats	Atovaquone PLUS azithromycin, Clindamycin PLUS quinine	[1]
2	Babeiosis	*Babesia gibsoni*	*Rhipicephalus sanguineus*	Severe headache, nausea, abdominal pain, hemolytic anemia, fever, chills, sweats	Atovaquone PLUS azithromycin, Clindamycin PLUS quinine	[47]
3	Babeiosis	*Other Babesia sp*	*Rhipicephalus sp.*	Flu-like symptoms, body aches, loss of appetite, nausea, or fatigue	Antiparasitic drugs,	[47]
4	Hepatozoonosis	Hepatozoon americanum	*Amblyomma maculatum*	fever, lethargy, decreased appetite, weight loss, muscle pain/weakness, reluctance to move, and discharge from the eyes and nose	Trimethoprim-sulfa, clindamycin, and pyrimethamine.	[33]
5	Hepatozoon canis	*Hepatozoon americanum*	*Rhipicephalus sanguineus*	Haemolymphatic tissues and causes anaemia and lethargy.	Imidocarb dipropionate at 5-6 mg/kg IM and Tab. Doxycycline	[47]
6	Tularemia	*Francisella tularensis*	*Ixodes scapularis Amblyomma americanum Dermacentor variabilis*	cough, chest pain, and difficulty breathing, swollen lymph nodes near the skin ulcer	Streptomycin, gentamicin, doxycycline, and ciprofloxacin	[52]
7	Rocky mountain	*Rickettsia ricketsii*	*Dermacentor variabilis*	Fever, chills, or loss of appetite, nausea or	Doxycycline, Monodox, Vibramycin,	[47]

S. No.	Disease	Organism	Vector	Symptom	Treatment	References
	spotted fever		*Dermacentor andersoni Rhipicephalus sanguineus*	vomiting, skin rashes or red spots, eye redness, headache, rash on the palms and soles, or sensitivity to light		
8	Q Fever	*Coxiella brunette*	*Dermacentor andersoni*	Pain in the abdomen or muscles, fatigue, high fever, malaise, chills, or night sweats, coughing, headache, nausea, or shortness of breath	Antibiotic doxycycline	[39]
9	Ehrlichiosis	*Ehrlichia chaffeensis*	*Amblyomma americanum, Ixodes scapularis*	Human Monocytic plasmolysis, fever, chills, malaise, nausea, diarrhoea	Doxycycline	[51]
10	Anaplasmosis	*Anaplasma phagocytophilum*	*Ixodes scapularis Ixodes pacificus*	Human Granulocytic plasmolysis, fever, headache, chills, and muscle aches.	Doxycycline single IM injection of long-acting oxytetracycline at a dosage of 20 mg/kg.	[3]

Tick-borne paralysis

Tick-induced paralysis is the most widespread and dominant form of tick toxicoses is caused by *Amblyomma aculatum* on the Mexican Pacific Coast [33]. Australian paralysis is caused by tick *Ixodes holocyclus* [34]. This tick species secrete toxins which produce positive inotropic responses in rat left ventricular papillary muscles and positive contractile responses in rat thoracic aortic rings [34]. Destruxin A secreted by *Rhipicephalus (Boophilus) microplus* ticks (Acari: Ixodidae) causes tetanic paralysis [35]. Tick secrete a highly paralytic and lethal venom cocktail of proteinaceous molecules contain neurotoxins HT-1, present in the saliva ticks despite several species possessing saliva of the Australian paralysis tick [36] (table 3).

Protozoan diseases

A huge diversity of ticks that spread tick-borne protozoan diseases in livestock are reported Middle East and North Africa [37]. Protozoans i.e. *Babesia divergens, B. venatorum*, and *B. microti* have also been detected in urban tick *Ixodes ricinus* populations in Europe [38]. Six ticks, including *Amblyomma triguttatum, Bothriocroton hydrosauri, Haemaphysalis novaeguineae, Ixodes cornuatus, Ixodes holocyclus,* and *Ixodestasmani* transmit *Coxiellaburnetii, Rickettsia australis, Rickettsia honei*, or *Rickettsia honeisubspmarmionii.* These bacterial pathogens cause Q fever, Queensland tick typhus (QTT), Flinders Island spotted fever (FISF), and Australian spotted fever (ASF) [39] (table 4).

Theileriais is caused by economically important, intra-cellular protozoa, which is transmitted by ixodid ticks. It infects both wild and domestic ruminants. In the mammalian host, parasites infect leukocytes and erythrocytes. *Theileria* sporozoites immortalize and transform host cells of haematopoietic origin [40]. *Theileria annulata* is a tick-transmitted protozoan parasite of cattle, which transforms cells of macrophage (Mphi) or B cell lineage [41]. *Theileria parva,* undergoes obligate sexual stage development in its tick vector *Rhipicephalus appendiculatus. R. appendiculatus* ticks are able to acquire *T. parva* parasites from infected cattle even in the absence of detectable parasitemia. *T. parva* transmission by *R. appendiculatus* is seen in East Cost Fever endemic regions [42]. Buffalo (synceruscaffer) are the natural host of *Theileria parva,* mainly non-diapausing populations of *R. appendiculatus* that was introduced from eastern Africa with cattle imported in 1901 [43]. Recombinant forms of *Theileria parva* and *Theileria annulata* sporozoite surface antigens induce protection against parasite challenge in cattle [44].

East Coast fever (ECF) is a devastating disease of cattle and a significant constraint to the improvement of livestock production in sub-Saharan Africa. The protozoan parasite *Theileria parvais* the etiologic agent of East Coast fever, an economically important disease of cattle in sub-Saharan Africa. East Coast fever (ECF) is a devastating disease of cattle and a significant constraint to the improvement of livestock production in sub-Saharan Africa. The protozoan parasite *Theileria parvais* the etiologic agent of East Coast fever, an economically important disease of cattle in sub-Saharan Africa. *Theileria parva* causes theileriosis infection of *H. anatolicum* with *T. lestoquardi. Theileria parvais* transmitted by the ixodid tick *Rhipicephalus appendiculatus*, is the cause of East Coast fever (ECF) [43]. This protozoan parasite is biologically transmitted by *Rhipicephalus appendiculatus* (Neumann) (Acari: Ixodidae) Babesiosis [45] (table 4).

The black-legged tick, *Ixodes scapularis,* is the primary vector to humans that transmit the protozoan parasite *Babesia microti* [46]. Ticks spread infection of bacterial genus *Rickettsia* mainly typhus, rickettsialpox, boutonneuse fever, African tick bite fever, Rocky Mountain spotted fever, Flinders Island spotted fever, and Australian tick typhus [47] (table 4).

Table 4: Important fungal diseases transmitted by various tick species

S. No.	TBDs	Species	Host	Vector tick species	Symptoms	References
1	Anaplasmosis	*Anaplasma phagocytophilum, A. platys, A. marginale, Abovis, A ovis, A central*	Ruminants, dogs, human	*Ixode spp, Dermacentor spp, Rhipicephalus spp, Haemaphysalis spp, Hyalomma spp, Ornithodorus spp*	Human Granulocytic plasmolysis, fever, headache, chills, and muscle aches	[1]
2	Mediterranean spotted fever	*Rickettsia canarii complex (Rhipicephlus sanguineus)*	Man	*Dog tick Rhipicephalus sanguineus*	Headache, fever and maculopapular rash	[11]
3	Ehrlichiosis	*Ehrlichia canis*	Dogs	*Rhi. Sanguineus?*	Human Monocytic plasmolysis, fever, chills, malaise, nausea, diarrhoea	[32]
4	CCHF	*CCHF virus*	Human	*H. marginatum, haemaphysalis*	Stomach pain and	[32]

S. No.	TBDs	Species	Host	Vector tick species	Symptoms	References
				spp, Rhipicephalusspp, I. ricinus	vomiting. Red eyes, a flushed face, a red throat, and petechiae	
5	Pacific Coast tick fever	*Rickettsia philipii (Dermacentor occidentalis)*	Horses, deer, cattle, lagomorphs, peccaries, porcupines, tapirs, desert bighorn sheep, and humans	*Dermacentor species*	Eschar or tissue necrosis	[33]
6	Theileriosis	*T. annulata, T. buffeli/orientalis/sergenti, T. ovis, T. equi*	Ruminants equid	*H. marginatum, H. anatolicum, Hexcavatum, H detritum, Haemaphysalis spp, Rhipicephalus*	Anemia and, in some cases, jaundice or hemoglobinuria.	[43]
6	Rocky Mountain Spotted fever	*Rickettsia rickettsia (Dermacentor variabilis, Dermacentoranders oni)*	Man, Dog, small mammals are the natural reservoirs in the wild	*Dermacentor variabilis and Dermacentor andersoni.*	Subclinical infection to severe or fatal multiorgan collapse. Blackened or crusted skin at the site of a tick bite.	[47]
7	African tick bite fever	*Rickettsia africae (Amblyomma)*	Ruminants, equids, candis, felids, rodents, human	*Rhipicephalus annulatus, Rhi. Bursa, Rhituranicus, Rhisanguineus, Hyalomma excavatum, H rufipes, H marginatum, H. dromedarii, Haemaphysalis punctate, Haeparva, Hae. sulcata, Dermacentor marginatus, D. reticulatus, Ixodes ricinus*	Severe headache, nausea, abdominal pain, hemolytic anemia, fever, chills, sweats	[47]
8	Cytauxzoonosis	*Cytauxzoonfelis*	Domestic cat	*star tick, Amblyomma americanum*	Necropsy, splenomegaly, hepatomegaly, enlarged lymph nodes, and renal edema	
9.	Bartonellosis (Cat scratch fever)	*Bartonella henselae*	Cat	*?*	Fever, headaches, fatigue, poor appetite, brain fog, muscle pain, and swollen glands around the head, neck, and arms.	
10	Hepatozoonosis	*Hepatozoon canis*	Candis felids	*Rhi. Sanguineus*	Fever, lethargy, decreased appetite, weight loss, muscle pain/weakness, reluctance to move, and discharge from the eyes and nose	
11	Aegypti anellosis	*Aegyptianella pullorum*	Duck	?	Parasitize the erythrocytes, infectious anemia".	
12	Tick-borne typhus	*R. hoogstraali, R. aeschlimanni, R. slovaca*	Human Dogs	*H. marginatum, H. aegyptium, H excavatum, D. marginatus, Haeparva*	High fever, nausea, malaise, diarrhea, and vomiting.	
13	Tularemia	*Francisella tularensis*	Human	*?*	cough, chest pain, and difficulty breathing, swollen lymph nodes near the skin ulcer	[52]
13	Candidatus R. vini	*R. vini*	Birds	*Ixodes arboricola, Haemaphysalis longicornis ticks*	Leukopenia and elevated hepatic enzyme levels	[58]
14	Rickettsiosis	*Rickettsia parker (Amblyommam aculatum)*	Small mammals and humans	*Dermacentor variabilis Dermacentor andersoni Rhipicephalus sanguine*	Rickettsial vasculitis, vascular inflammation	[63]
15	Lyme Borreliosis	*Borrelia burgdorferi, Bor. Turcica sp. Nov*	Human, dogs, horses	*I. ricinus, H. aegyptium, H excavatum, D. marginatus, Haeparva*	Circular rash with red oval or bull's-eye marks appear anywhere on the body, fatigue, joint pain and swelling, fever, swollen lymph nodes	[64]
16	Canine filariosis	*Acanthocheion emareconditum*	Dogs	*?*	Weight loss, cough, fatigue	[75]
	Dermatophytosis	*Trichophyton spp, M gypseum, and less commonly M canis*	human and animal	*Rhipicephalus microplus*	the dermatologic disease of nails, skin and hair	[89]
	Histoplasmos	*Histoplasma*	human and	*Ticks andbadger*	Body ache, fever, chills,	[91]

S. No.	TBDs	Species	Host	Vector tick species	Symptoms	References
	is	capsulatum	animal		resemble those of the flu.	
	Ring worm *Dermatophilosis*	*Dermatophilus congolensis*	horses, cattle, sheep, goats and humans.	*Ixodes*	Red, scaly and itchy patches, hair loss	[91]
	Conidiosis	*Metarhizium spp. Beauveria bassiana*	human and animal	*Rhipicephalus microplus*	fever and chills	[92]
17	TBRF	*Bor. Crocidurae*	Rodents	*Ornithodoro serraticus*	Fatigue, fever, loss of appetite, malaise, night sweats or sweating, loss of muscle, phlegm, severe unintentional weight loss, shortness of breath, or swollen lymph nodes	
18	Hemoplasmosis	*Mycoplasma haemofelis*	Cat	?	Lethargy, weakness, reduced appetite, dehydration, weight loss and intermittent pyrexia	

Lumpy skin disease

The Lyme disease-causing organism, *Borrelia burgdorferiis* transmitted into the mammalian host by an infected-tick bite Lumpy skin disease (LSD). This causes economic losses to the cattle industry in Africa and the near and Middle East. Ixodid ticks include the genera *Rhipicephalus* (i.e., brown dog tick), *Dermacentor* (i.e., American dog tick, Rocky Mountain wood tick, Pacific or West Coast ticks), *Ixodes* (i.e., shoulder tick of North America, deer tick, British dog tick [Europe]), *Amblyomma* (i.e., black-legged tick, Lone Star ticks), and *Haemophysalis* (i.e., yellow dog ticks [Africa and Asia]) and cause lumpy skin disease (table 4).

Bacterial diseases

Ticks harbor and, in many cases, transmit to their vertebrate hosts, a wide variety of pathogenic, pathogenic and endosymbiotic microorganisms. Ticks are the most important vectors of human pathogens, mainly the emergence of Lyme disease and human ehrlichiosis, respectively [51]. Lyme disease is caused by *Borrelia burgdorferi,* its 15 forms have been identified throughout the world, including 8 rockets, 3 ehrlichiae, and 4 species. Important tick-borne bacterial diseases are rickettsioses, ehrlichioses Lyme disease, relapsing fever braless, tularemia, Q fever, particularly those regarded as emerging diseases. Tick bites transmit bacteria which is a biggest challenge for clinicians [52]. The obligate intracellular bacterium *Ehrlichia ruminantium* (ER) causes hot water, a fatal tick-borne disease in livestock [53]. *Ehrlichia chaffeensis* is a tick-transmitted obligate intracellular pathogenic bacterium which causes human Monocytic ehrlichiosis and putative host cell targets during infection [54]. Tick-borne relapsing fever is evoked by spirochetes which are blood-borne pathogens transmitted through the saliva of soft ticks [55]. Ticks cause multiple bacterial diseases, including *Anaplasma phagocytophilum* (anaplasmosis), *Borrelia burgdorferi* and *Borrelia mayonii* (Lyme disease), *Borrelia miyamotoi* (relapsing fever-like illness named *Borrelia miyamotoi* disease), and *Ehrlichia muriseauclairensis* (a minor causative agent of ehrlichiosis) It also transmits *Borrelia burgdorferi* (sensustricto) in eastern North America [56]. Ticks *Ixodes scapularis* and *Ixodes ricinus* are infected by *Borrelia burgdorferis. S. Ehrlichia ruminantium*. *Ixodes ricinus is* the principal vector of the largest variety of microorganisms, bacteria and piroplasms [57]. High prevalence of ticks infected with *Borrelia burgdorferis.* cause Lyme borreliosis. This disease is prevalent in urbanized areas in Europe. Other important emerging pathogens, including bacteria of the order Rickettsiales (*Anaplasma phagocytophilum*, *"Candidatus Neoehrlichia mikurensis,"* *Rickettsia Helvetica*, and *R. monacensis*), and *Borrelia miyamotoi* (table 4).

Tick-borne babesiosis

Tick-borne babesiosis is an emerging zoonosis. This is a well-recognized malaria-like disease that occurs worldwide [58]. *Babesiosis is* an important tropical tick-borne haemoprotozoan disease occurs in dogs. Babesiosis is a potentially life-threatening illness caused by intra-erythrocytic protozoan parasites of the genus *Babesia*. This pathogen is transmitted most commonly by *Ixodes* ticks, it also rarely occurs through blood transfusion or congenitally. This is clinically manifested by anorexia, dehydration, temperature, dullness/depression, diarrhea/constipation, pale mucosa, hepatomegaly, vomiting/nausea, splenomegaly, distended abdomen/associates, yellow colored urine, emaciation/weight loss, and ocular discharge [59]. Antibiotics such as atovaquone plus azithromycin or clindamycin and quinine are used to treat this disease. The disease causes heavy mortality in high-risk populations in spite of anti-biotic therapy [60]. Development of modern molecular tools led to the discovery and identification of emerging or new tick-borne microorganisms, mainly tick-borne pathogenic bacteria and symbionts with unknown zoonotic potential [61]. A small bacterial diversity which infests livestock across reported from tick species was identified on the basis of bacterial 16SrRNA [62]. The most important genera identified are *Ralstonia*, *Clostridium*, *Staphylococcus, Rickettsia, Lactococcus, Lactobacillus, Corynebacterium, Enterobacter,* and *Enterococcus*. The *Candidatus Rickettsia* emblem is reported in *Rhipicephalus microplus, Hyalomma anatolicum*, and *H. dromedary* tick species. These also carry *T. emulates* [62].

Lyme borreliosis (LB) spirochetes have been isolated tick cell lines, primary cell cultures and organ cultures and adult *Ixodes ricinus, Dermacentor marginatus* and *Dermacentor reticulatus* ticks. Camels and/or the ticks infesting them are disease reservoirs of zoonotic Q fever (C. Burnett), ehrlichiosis (*E. chaffeensis*) and rickettsiosis (*R. africae*), which pose public health threats to pastoralist communities [63]. Amblyomma ticks are vectors of heartwater disease in domestic ruminants, caused by the rickettsial pathogen *Ehrlichia ruminantium* in sub-Saharan Africa [64]. *Rickettsia spp., Babesia spp., Anaplasma marginale, Anaplasma spp.* and Coxiella-like organisms have been identified in one-humped camels *(Camelusdro medarius*) in Nigeria [65] (table 4).

Members of the genus Spiroplasma are Gram-positive bacteria without cell walls. Some Spiroplasma species can cause disease in arthropods such as bees, whereas others provide their host resistance to pathogens [66]. The presence of the bacteria in the tick eggs used to initiate the primary cultures confirms that transovarial transmission of this Rickettsia occurs [67]. *Spiroplasma ixodetis* and the Mycobacterium isolate belonged to the *Mycobacterium chelonae* are also identified [68]. *Babesia gibsoni* transmitted by larval progeny of *Haemaphysalis longicornis* and *H. hystricisticks* and *B. vogeli* from larvae of *R. sanguineus* have been isolated [69].

Anaplasmosis

Anaplasmosis is an emerging zoonotic disease with a natural enzootic cycle. This disease is spread by *Ixodes ricinus* and *Ixodes* *scapularis* are the principal vector of *Anaplasma phagocytophilum. Anaplasma phagocytophilum* causes human granulocytic anaplasmosis, one of the most common tick-borne diseases in North America. This unusual obligate intracellular pathogen selectively persists within polymorphonuclear leukocytes. Tick also transmits Tofla virus; a Nairovirus of the Crimean-Congo hemorrhagic fever group found in Japanese ticks.

Ixodes scapularis transmits a group of pathogens, including *Borrelia burgdorferi*, *Babesia microti,* and *Anaplasma phagocytophilum*, the causative agents for Lyme disease, Babesiosis, and anaplasmosis, respectively. Lyme disease is transmitted by *I. scapulars* that impose significant implications regarding clinical diagnosis, and treatment in human population in an endemic area [70].

The ixodid genus includes important disease vectors of animals and humans. Ticks transmit disease organisms such as the bacterium *Borrelia burgdorferi* that causes Lyme disease and tick-borne encephalitis (TBE) virus through saliva. In addition, the protozoan Babesia and the bacterium *Anaplasma* cause diseases in livestock. Rocky Mountain spotted fever, a systemic tick-borne illness is caused by an obligate intracellular bacterium *Rickettsia rickettsii*. This is associated with widespread infection of the vascular endothelial [71] Ticks carry zoonotic disease viruses from animals to humans and generate severe health-related consequences to man, livestock, dogs, sheep, cows, buffaloes, antelopes, horses, ferrets, and cats [72] (table 4).

Lyme disease

Ticks are also responsible for the transmission of several animal and human pathogens, including the causal agents of Lyme borreliosis, tick-borne encephalitis, human granulocytic anaplasmosis and human babesiosis [73]. Lyme borreliosis (LB) and other *Ixodes ricinus*-borne diseases (TBDs) are diseases that emerge from interactions of humans and domestic animals with infected ticks in nature [74]. Ixodid ticks are notorious blood. sucking ectoparasites and are completely dependent on blood meals from the hosts. Lyme paralysis is caused by Ixodes-tick transmitted spirochete *Borrelia burgdorferi* consulate bacteria transmitted to humans by the bite of hard ticks, Lyme disease is the commonest worldwide [75]. This disease is a potential health threat to Canines, mainly dogs and lives stocks. It manifests with arthritis-induced lameness, anorexia, fever, lethargy, lymph adenopathy and, in some cases, fatal glomerulo–nephritis. The Lyme disease parasite *Borrelia burgdorferi,* possesses a number of outer membrane proteins that are differentially regulated during its life cycle. During natural infection with the agent of Lyme disease, *Borrelia burgdorferi*, spirochetes are delivered with vector saliva, which contains anti-inflammatory and antihemostatic activities [76]. The vaccine could be an efficient approach to decrease Lyme disease incidence. Lyme disease transmission, with the purpose to highlight various aspects in the ecological cycle of disease transmission to be incorporated, including the growth of ticks with different stages in the life cycle, the seasonality, host diversity, spatial disease pattern. Due to host short distance movement and bird migration, co-infection with other tick-borne pathogens, and climate change impact [77]. Small rodents serve as reservoir hosts for tick-borne pathogens, such as the spirochetes causing Lyme disease [78]. *Lyme borreliosis* patients show variable clinical manifestations, i.e. pruritus, swollen joint, pain, lymphadenopathy and ulceration, respectively [79]. For control of Lyme borreliosis and other *Ixodesricinus*-borne diseases multidisciplinary approaches ecological, medical, veterinary and cultural must be required. *Lyme borreliae*proteins promote vertebrate host blood-specific spirochete survival in *Ixodesscapularis* nymphs using artificial feeding chambers. BBA52 and Lp6.6 protein play an important role in promoting spirochete survival in nymphal ticks fed on human or quail blood. The ability of spirochetes to survive in ticks during blood feeding is thought to be essential for *Lyme borreliae* to be transmitted to different vertebrate hosts. Identification of Lyme borreliaeproteins promoting vertebrate host blood-specific spirochete survival in *Ixodesscapularis* nymphs using artificial feeding chambers [80]. Lyme disease in caused by *Borrelia buisensulatorgdorferi.* There are various parallel proteins which directly or indirectly contribute to the natural cycle of *B. burgdorfer i*infection. There is a need to identify discrete molecular interactions between spirochetes and tick components, which play critical roles in pathogen persistence and transmission by the arthropod vector [81] (table 4).

Rickettsioses

Rickettsioses have epidemiological importance that includes pathogens, vectors, and hosts are caused by dog tick *Rhipicephalussanguineus* and the camel ticks *Hyalommadromedarii.* These are important vectors and reservoirs of Rickettsiae vectors of Rickettsioses (Acari: Ixodidae) infected male ticks do sexual transmission of spotted fever group rickettsiae. Rickettsiae have been detected in spermatogonia, spermatocytes, and maturing spermatids [82]. Common marmosets are susceptible to a number of bacterial infections, which may be exotic, causing sporadic but occasionally severe disease. They secrete potential toxic molecules in the blood remains Ixodid ticks, in combination with the bacterial transmission; induce a robust inflammatory response at the blood-feeding site. Hard Tick *Amblyomma variegatum* causes theileriosis is a blood piroplasms disease that adversely affects livestock, especially in tropical and sub-tropical countries. It is caused by haemoprotozoan found in hard ticks. Tick-borne pathogens (TBPs), especially *Anaplasma phagocytophilum*, cause disease in grazing livestock. Human seven-trans-membrane (7TM) G protein-coupled chemokine receptor is a large family of leukocyte chemoattractant receptors. It regulates immune system development and function, in large part by mediating leukocyte trafficking during infection or wound healing. *Borrelia spp.* generates production of four inflammatory cytokines. Tick-host interactions during feeding are complex, with host immune responses influenced by biological differences in tick feeding and individual differences within and between host species. One of the first encounters for spirochetes entering the vertebrate host skin occurs with local antigen-presenting cells. While to, tick-associated *Borrelia sp.* evoke pathogens cytokine responses in THP-1-derivedmacrophages after exposure to selected borreliae, including a non-pathogen [83]. It is a multiprotein complex (T4Es) that allows the bacteria to evade host defenses and, to subvert host cell processes to their own advantage [84] (table 4).

Endosymbionts in Soft ticks

Ticks Bacterial endosymbionts of ticks are of interest due to their close evolutionary relationships with tick-vectored pathogens. For instance, whereas many ticks contain Francisella-like endosymbionts (FLEs), others transmit the mammalian pathogen *Francisellatularensis* [85]. *D. Variabilis* is normally resistant to entomopathogenic fungus *Metarhizium anisopliae.* Female ticks harbor *S. brevicaulis a* mycobiont internally [86]. *Coxiella burnetii,* the logic agent of acute Q fever and chronic endocarditis, is an intracellular form that occupies a large lysosome-derived acidic vacuole. *C. burnetiia* bacterium grows with in mammalian cells obligate intracellular replication in a hostile manner [87]. *Ixodes scapularis* and *Dermacentor andersoni,* infected with an endosymbiont, *Rickettsia peacockii* Lyme disease spirochete, *Borrelia burgdorferi. Rickettsia peacockii* non-pathogenic obligate intracellular bacterium found as an endosymbiont in *Dermacentor andersoni* ticks in the western USA and Canada. Its presence in ticks is correlated with the reduced prevalence of *Rickettsia rickettsii*, the agent of Rocky Mountain spotted fever [88].

Fungal diseases

Although there are over 250 zoonotic diseases, only 30-40 of them involve dogs and cats. Transmission of zoonotic infections occurs via bites, scratches or touch; exposure to saliva, urine or faeces; inhalation of particles or infectious aerosols; contact with a transport or intermediate host (e. g., ticks, fleas); or exposure to contaminated water, soil or vegetation. This paper summarizes the most important common zoonotic dermatological diseases of dogs and cats. The most common dermatological sinuses are flea and tick infestations and the diseases they transmit; dermatophytosis; and mite infestations (Sarcoptes and Cheyletiella). Prevention of zoonotic infestations or infections can be accomplished easily by the use of routine flea and tick control, screening of new pets for dermatophytosis, and routine hand-washing [89] Pets like dogs and cats are responsible for a series of sonatas disorders. Pets like dogs and cats are responsible for a series of sonatas disorders. Some of these diseases are inflicted bites, scratches or licking. Others result from a close contact with fur, or are transmitted by osteoporosis or by the contaminated environment. Some systemic infectious and parasitic diseases are transmitted from animals to humans and vice versa. Such a situation may lead to endemic problems in some communities.

Fungal infections associated with zoonotic spread are an important public health problem at global. There are numbers most common fungal diseases, such as: dermatophytosis, sporotrichosis, and histoplasmosis, which are seen in humans [90]. Histoplasmosis is a fungal disease associated with bat guano (stool) (CDC0 and is a type of lung infection. It is caused by inhaling *Histoplasma capsulatum* fungal spores. Coccidioidomycosis is an infection usually caused by inhaling the spores ("seeds") of either *Coccidiodes immitis* or *Coccidioides posadasii* fungi). Ticks are vectors or reservoirs in the transmission of pathogenic fungi such as (Dermatophilosis) [91]. *M. anisopliae sensulato* and *Beauveria bassiana* infect tick cuticle that further transmit this fungi to humans [92]. Diagnosis of tick saliva disease pathogens Ticks are blood-sucking arthropods which largely affect host health, mainly vertebrate host's and affect hemostasis, cause inflammation, and weaken immunity [93]. Tick salivary gland secretions contain a diversity of pathogens, including viruses, bacteria and eukaryotes [94]. Ticks used saliva during blood sucking as an anti-coagulant and release several types of pathogens into the host blood. It makes them versatile vectors of several diseases for humans and other animals. When a tick feeds on an infected host, the pathogen reaches the gut of the tick and must migrate to its salivary glands via hemolymph to be successfully transmitted to a subsequent host during the next stage of feeding [95].

Tick saliva is increasingly recognized as a rich source of bioactive molecules with specific functions. Ticks use their saliva to overcome the innate and adaptive host immune systems. Their saliva is a rich cocktail of molecules, including proteins, peptides, lipid derivatives, and recently discovered non-coding RNAs that inhibit or modulate vertebrate immune reactions. So many salivary gland molecules that work as antigens have been isolated from tick saliva. These have been characterized and shown to be promising candidates for drug development for vertebrate immune diseases. Salivary proteins are part of the host-tick interface and play vital roles in the tick feeding process and the host infection by tick-borne pathogens. These could be used as important targets for immune interventions. Transcriptome provides a valuable reference database for ongoing proteomics studies of the salivary glands [96].

Tick salivary compounds are of immense immune-pharmacological importance of non-coding RNAs that might be exploitable as immunomodulatory therapies [97]. The majority of salivary secretion substances are expressed by the parasite salivary gland and secreted in tick saliva. Characterization of cattle ticks salivary gland gene expression in tick-susceptible and tick-resistant hosts may be helpful in putative targets for the control of tick infestations. These genes might be involved in the mechanism of stress response during blood feeding [98]. Natural infection of TBEV and WNV can be identified by cross-reactive ELISAs screening [99] and confirmed by serum neutralization tests [100]. Analysis of the secondary protein structures using FTIR-ATR show both *in vivo* and membrane-fed cement cones contain βsheets, but only *in vivo* cement cones contain helical protein structures. Proteomic analysis is used to identify both secreted and non-secreted tick proteins [101]. Sialotranscriptomics is used for proteomics studies of the salivary glands and saliva of various tick species. The bacterial diversity across these tick species was assessed by bacterial 16S rRNA gene sequencing using a 454-sequencing platform about 10 of the different tick species infesting livestock [102]. BLSOM program is used to know phylogenetic relationships based on the similarity of oligonucleotide frequencies and functional annotation by BLASTX similarity searches [103].

BLSOM analysis is used to detect microorganisms belonging to the phylum chlamydia in some tick species. These could be identified by new methods by selectively amplify microeukaryote genes in tick-derived DNA by blocking the amplification of the 18S rRNA gene of ticks. Using artificial nucleic acids, mainly peptide nucleic acids (PNAs) and locked nucleic acids (LNAs). Additionally, the PNA-or LNA-based methods were suitable for pancreatic analyses, whereas the UNonMet-PCR method was particularly sensitive to fungi [104]. For detection of TBE virus and Bluetongue virus in ticks and real-time RT-PCR is also done [105] Indirect immunofluorescence is applied for detection of *Borrelia* spirochetes [106]. The ELISA test is also used for viral purified nucleoprotein for virus infection [107]. Tick-borne zoonotic infections are among the most diffuse vector borne diseases. These are caused by different microorganisms: *Babesia spp., Borrelia spp., Rickettsia spp., Ehrlichia spp., Francisella tularensis, Coxiella burnetii)* and tick-borne encephalitis virus. *Babesiosis* is caused by the protozoa (sporozoa) *Babesiamicroti.* This is quite rare in humans in Europe. Lyme borreliosis caused by the spirochete *Borrelia burgdorferi.* This is identified by using PCR assay [108]. OspA-based PCR on cerebrospinal fluid (CSF) samples from patients with Lyme neuroborreliosis. Besides this, DNA sequence analysis and PCR assays is perfomedon the amplicon to determine the genospecies of Borreliapresent in the CSF [109]. The microbiological diagnosis is also done by serologic techniques (IFA, EIA, WB) and by mainta *in vitro* culture of microbes and DNA amplification methods [110]. *In vitro* culture is also done in isolation of microbial antigens that increased the diagnostic sensitivity and accuracy in clinical isolates [111] (table 4).

16S rRNA gene sequences are considered as good markers of the presence of the internal microbiome of tick, mainly Cayenne tick *Amblyomma cajennense* (since strict). Surface sterilization methods are used for studying internal micro biodiversity [112]. The variety of *Borrelia burgdorferi sensulato* (*B. burgdorferi)* genospecies leads show differences in clinical isolates of *Lyme borreliosis* (LB). In addition, Lyme *Borreliageno species* were subsequently identified by sequence analysis and real-time polymerase chain reaction (PCR) amplification of the 16S rRNA gene [112]. Tick Microbiomes for *Borrelia species* in *Ixodes ricinus* show differences. These can be identified by using sequence analyses of the 16S rRNAgene [113]. *Borrelia burgdorferi* genospecies in *Ixodes ricinus* ticks were also identified by using by dark field microscopy (DFM) [114]. PCR method was applied, in which a fragment of the flu gene was used as a marker [115]. *Borrelia species* transmitted by hard ticks bacteria in ixodid ticks infesting domestic animals were identified by using quantitative (q) real-time PCR followed by standard PCR and sequencing to identify the species [116]. Real-time PCR targeting based on the ospA gene was used for the detection of *Borrelia burgdorferi sensustricto, Borrelia garinii, Borrelia afzelii* and *Borrelia valaisiana* [117]. PCR also used to find differences in various disease biotypes of spirochaetes an agent of Lyme disease [118]. *Borrelia sp.* In an *Amblyomma varanense* was collected from snake Python reticulates [119] (table 4. Discrete molecular interactions between spirochetes and tick components also have been discovered by using DNA-based molecular markers. These play critical roles in pathogen persistence and transmission by the arthropod vector. In addition, various antigens of immuno-pharmacological importance were isolated from tick salivary glands. In addition, sequence analysis was done for identifying non-coding RNAs that could be used in immunomodulatory therapies.

Control of ticks

Ticks are important human and animal parasites and vectors of many infectious diseases Control of tick activity is an effective tool to reduce the risk of contracting tick-transmitted diseases. For tick control generally, conventional acaricides are used [120]. For tick control oral treatment of pet is doing. For this purpose oral administration of afoxolaner (NexGard™) and fluralaner (Bravecto™) with topically applied permethrin/imidacloprid (Advantix®) was followed to check transmission of *Ehrlichia canis* by infected *Rhipicephalus sanguineus* ticks to dogs.

For tick control oral treatment of pet is doing. For this purpose oral administration of afoxolaner (NexGard™) and fluralaner (Bravecto™) with topically applied permethrin/imidacloprid (Advantix®) was followed to check transmission of *Ehrlichiacanis* by infected *Rhipicephalus sanguineus* ticks to dogs. Advantix® effectively blocked the transmission of *E. canis* to dogs and provide adequate protection against monocytic ehrlichiosis [121]. In ticks, the attraction–aggregation–attachment, assembly may be controlled by ticks host kairomones. For safe control of ticks lure-and-kill and lure-enhanced biocontrol strategies based on employmentof various pheromones were also tried [122]. For better control establishing inter-relationship between ticks and the pathogens is highly important. It will provide idea about the mechanisms of acquisition, persistence and transmission patterns in various hosts. For successful control of ticks molecular drivers for tick-borne diseases, mainly responsible for tick-pathogen molecular interactions of bacteria, viruses, and protozoa affecting human and animal health are to be studied.

The tick immunobiology plays a significant role in establishing and transmitting many pathogens to their hosts. Anti-tick vaccines could interrupt blood-feeding ticks; this might be a good method for tick control [123]. For control of black-legged ticks rodent-targeted oral vaccines against *B. burgdorferi* and rodent-targeted antibiotic bait are also used. Besides this, new explorations be made for finding new potential candidates for the development of anti-vector vaccines (a form of transmission-blocking vaccines) against a wide range of hard and soft ticks [124]. Protease inhibitors (PIs) that primarily target serine protease-mediated pathways also disrupt blood feeding [125]. Non-pathogenic microorganisms may also play a role in driving transmission of tick-borne pathogens (TBP), with many potential implications for both human and animal health [126].

Larval tick abundance increases the prevalence, and incidence Lyme disease. For cultural control of ticks, spatially diffuse space, including backyards, neighbourhood green spaces, and public recreation areas must be regularly treated with anti-tick formulations In addition, stone walls, wood chip barriers separating the lawn from adjacent forest, bird feeders, fencing, wood stores, and prevalence of bushy plants must be removed. Massive tick control could be achieved by controlling the emergence and the movements of larval tick. More often, larval tick abundance increase the prevalence of disease incidence. Therefore, the presence or absence of pets and outdoor animals must be fully checked. For successful control of ticks, all host animals must be shifted to clean places and old places must be treated routinely. For driving the massive control ticks' new alternative methods must be developed to check the tick infection. For this purpose natural cycle of ticks, and tick-parasite dynamics must be studied. In addition, various aspects in the ecological cycle of disease transmission to be incorporated, including the growth of ticks with different stages in the life cycle, the seasonality, host diversity, spatial disease pattern due to host short distance movement and bird migration, co-infection with other tick-borne pathogens, and climate change impact.

For control of ticks identification of critical elements of the pathogens' lifecycle is highly important [127]. There has been increasing trends in disease occurrence and movement associated with the global movement of humans and global trade of animals. Hence, for the successful control study of tick ecology and tick born-disease transmission and vaccination are equally important integrated tick management consists of the systematic combination of at least two control technologies can reduce selection pressure in favor of acaricide-resistant individuals, while maintaining adequate levels of animal production [128]. Disease control and prevention could be achieved effectively through good integration between public health, veterinary medicine and animal management, and ecological approaches. For successful management mitigation of tick-associated negative social effects is highly essential [129]. Responsibility will be distributed to individual persons and professionally staffed tick-management programs [130]. To reduce the risk, disease burden and costs of TBDs both environmental and health policies must be implemented at a global level for mitigation of tick associated morbidities and economic loss [131, 132].

CONCLUSION

Ticks are major ecto-paraistesof animal hosts, which transmit large numbers of pathogenic infectious agent's virus, bacteria, protozoans and fungi which generate various zoonotic diseases in man and dairy farm animals or livestock. The sole source of transmission of infection is tick saliva that assists them in blood feeding by inhibiting blood coagulation. Ticks borne diseases severely affecting human health and are more dangerous than envenomation. Ticks saliva is a rich cocktail of molecules, including proteins, peptides, lipid derivatives, and recently discovered non-coding RNAs that inhibit or modulate vertebrate immune reactions. So many salivary gland molecules that work as antigens have been isolated from tick saliva. These have been characterized and shown to be promising candidates for vaccine production and drug development. Tick control is possible by searching new potential candidates for the development of anti-vector vaccines (a form of transmission-blocking vaccines) against a wide range of hard and soft ticks Protease inhibitors primarily target serine protease-mediated pathways can be used for disruption of blood feeding. Plant repellents, herbal formulations, oils, poison baits and cultural control of ticks can reduce their population. For control of ticks identification of critical elements of the pathogens' lifecycle is highly important. Disease control and prevention could be achieved effectively through good integration between public health, veterinary medicine and animal management, and ecological approaches. For successful management mitigation of tick-associated negative societal effects is high essential. Responsibility will be distributed to individual persons and professionally staffed tick-management programs. To reduce the risk, disease burden and costs of TBDs both environmental and health policies must be implemented at a global level for mitigation of tick-associated morbidities and economic loss.

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CONFLICT OF INTERESTS

Declared none

REFERENCES

1. Pienaar R, Neitz AWH, Mans BJ. Tick paralysis: solving an enigma. Vet Sci. 2018;5(2):5(2):53. doi: 10.3390/vetsci5020053, PMID 29757990.
2. Wallmenius K, Barboutis C, Fransson T, Jaenson TG, Lindgren PE, Nystrom F. Spotted fever Rickettsia species in Hyalomma and Ixodes ticks infesting migratory birds in the European Mediterranean area. Parasit Vectors. 2014;7:318. doi: 10.1186/1756-3305-7-318, PMID 25011617.
3. Kovacova E, Vavrekova M, Lukacova M, Daiter AB, Tokarevich NK, Karceva NA. Immunochemical and antigenic characterization of Coxiella burnetii strains isolated in Europe and Mongolia. Eur J Epidemiol. 1994;10(1):9-15. doi: 10.1007/BF01717445, PMID 7957797.
4. Tajeri S, Razmi G, Haghparast A. Establishment of an artificial tick feeding system to study theileria lestoquardi infection. Plos One. 2016;11(12):e0169053. doi: 10.1371/ journal.pone.0169053, PMID 28036364.
5. Kazimirova M, Hamsikova Z, Spitalska E, Minichova L, Mahrikova L, Caban R. Diverse tick-borne microorganisms identified in free-

living ungulates in Slovakia. Parasit Vectors. 2018;11(1):495. doi: 10.1186/s13071-018-3068-1, PMID 30176908.
6. Garcia Vozmediano A, Tomassone L, Fonville M, Bertolotti L, Heylen D, Fabri ND. The genetic diversity of Rickettsiella symbionts in Ixodes ricinus throughout Europe. Microb Ecol. 2021. doi: 10.1007/s00248-021-01869-7, PMID 34580739.
7. Pierard GE, Pierard Franchimont C, Arrese JE, Nikkels AF, Paquet P, Hermanns Le T. Cutaneous zoonoses transmitted by dogs and cats [Cutaneous zoonoses transmitted by dogs and cats]. Rev Med Liege. 1998;53(9):532-6. PMID 9834676.
8. Ledger KJ, Beati L, Wisely SM. Survey of ticks and tick-borne rickettsial and protozoan pathogens in ESwatini. Pathogens. 2021;10(8):1043. doi: 10.3390/pathogens10081043, PMID 34451507.
9. Aguilar Diaz H, Quiroz Castaneda RE, Salazar Morales K, Cossio Bayugar R, Miranda Miranda E. Tick immunobiology and extracellular traps: an integrative vision to control of vectors. Pathogens. 2021;10(11):1511. doi: 10.3390/ pathogens10111511, PMID 34832666.
10. Uiterwijk M, Ibanez Justicia A, van de Vossenberg B, Jacobs F, Overgaauw P, Nijsse R. Imported hyalomma ticks in the netherlands 2018-2020. Parasit Vectors. 2021;14(1):244. doi: 10.1186/s13071-021-04738-x, PMID 33962655.
11. Buczek W, Koman Izko A, Buczek AM, Buczek A, Bartosik K, Kulina D. Spotted fever group rickettsiae transmitted by dermacentor ticks and determinants of their spread in Europe. Ann Agric Environ Med. 2020;27(4):505-11. doi: 10.26444/aaem/120602, PMID 33356053.
12. Lasala PR, Holbrook M. Tick-borne flaviviruses. Clin Lab Med. 2010;30(1):221-35. doi: 10.1016/j.cll.2010.01.002, PMID 20513549.
13. Estrada Pena A, de la Fuente J. The ecology of ticks and epidemiology of tick-borne viral diseases. Antiviral Res. 2014;108:104-28. doi: 10.1016/j.antiviral.2014.05.016, PMID 24925264.
14. Rizzoli A, Rosa R, Mantelli B, Pecchioli E, Hauffe H, Tagliapietra V. Ixodes ricinus, transmitted diseases and reservoirs. Parassitologia. 2004;46(1-2):119-22. PMID 15305699.
15. Bohm B, Schade B, Bauer B, Hoffmann B, Hoffmann D, Ziegler U. Tick-borne encephalitis in a naturally infected sheep. BMC Vet Res. 2017;13(1):267. doi: 10.1186/s12917-017-1192-3, PMID 28830430.
16. Khamassi Khbou M, Ayadi O, Al-Hosary AA, Darghouth MA, Gharbi M. Knowledge and perception on ticks and tick-borne diseases among veterinary medicine students from the North African countries of Algeria, Egypt, and Tunisia. Parasite Epidemiol Control. 2020;11:e00169. doi: 10.1016/j.parepi.2020.e00169, PMID 32885058.
17. Kuo CC, Lin YF, Yao CT, Shih HC, Chung LH, Liao HC. Tick-borne pathogens in ticks collected from birds in Taiwan. Parasit Vectors. 2017;10(1):587. doi: 10.1186/s13071-017-2535-4, PMID 29178908.
18. Klaus C, Ziegler U, Hoffmann D, Press F, Fast C, Beer M. Tick-borne encephalitis virus (TBEV) antibodies in animal sera–occurrence in goat flocks in Germany, longevity and ability to recall immunological information after more than six years. BMC Vet Res. 2019;15(1):399. doi: 10.1186/s12917-019-2157-5, PMID 31694666.
19. Reynolds ES, Hart CE, Hermance ME, Brining DL, Thangamani S. An overview of animal models for arthropod-borne viruses. Comp Med. 2017;67(3):232-41. PMID 28662752.
20. de la Fuente J, Antunes S, Bonnet S, Cabezas Cruz A, Domingos AG, Estrada Pena A. Tick-pathogen interactions and vector competence: identification of molecular drivers for tick-borne diseases. Front Cell Infect Microbiol. 2017;7:114. doi: 10.3389/fcimb.2017.00114, PMID 28439499.
21. Hutchinson ML, Strohecker MD, Simmons TW, Kyle AD, Helwig MW. Prevalence rates of borrelia burgdorferi (Spirochaetales: Spirochaetaceae), Anaplasma phagocytophilum (Rickettsiales: Anaplasmataceae), and babesia microti (Piroplasmida: Babesiidae) in host-seeking ixodes scapularis (Acari: Ixodidae) from pennsylvania. J Med Entomol. 2015;52(4):693-8. doi: 10.1093/jme/tjv037, PMID 26335476.
22. Edwards MJ, Barbalato LA, Makkapati A, Pham KD, Bugbee LM. Relatively low prevalence of Babesia microti and Anaplasma phagocytophilum in Ixodes scapularis ticks collected in the lehigh valley region of eastern Pennsylvania. Ticks Tick Borne Dis. 2015;6(6):812-9. doi: 10.1016/j.ttbdis.2015.07.009, PMID 26318263.
23. Pokutnaya D, Molaei G, Weinberger DM, Vossbrinck CR, Diaz AJ. Prevalence of infection and co-infection and presence of rickettsial endosymbionts in ixodes scapularis (Acari: Ixodidae) in connecticut, USA. J Parasitol. 2020;106(1):30-7. doi: 10.1645/19-116, PMID 31971489.
24. Ruzek D, Dobler G, Donoso Mantke O. Tick-borne encephalitis: pathogenesis and clinical implications. Travel Med Infect Dis. 2010;8(4):223-32. doi: 10.1016/j.tmaid.2010.06.004, PMID 20970725.
25. Suss J, Schrader C. Tick-borne human pathogenic microorganisms found in Europe and those considered nonpathogenic. Part I: ticks and Viruses. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2004;47(4):392-404. doi: 10.1007/s00103-003-0766-3, PMID 15205783.
26. Tokarz R, Sameroff S, Leon MS, Jain K, Lipkin WI. Genome characterization of Long Island tick rhabdovirus, a new virus identified in Amblyomma americanum ticks. Virol J. 2014;11:26. doi: 10.1186/1743-422X-11-26, PMID 24517260.
27. Charrel RN, Attoui H, Butenko AM, Clegg JC, Deubel V, Frolova TV. Tick-borne virus diseases of human interest in Europe. Clin Microbiol Infect. 2004;10(12):1040-55. doi: 10.1111/j.1469-0691.2004.01022.x, PMID 15606630.
28. Xu L, Guo M, Hu B, Zhou H, Yang W, Hui L. Tick virome diversity in Hubei Province, China, and the influence of host ecology. Virus Evol. 2021;7(2):veab089. doi: 10.1093/ve/veab089, PMID 34804590.
29. Harvey E, Rose K, Eden JS, Lo N, Abeyasuriya T, Shi M. Extensive diversity of RNA viruses in Australian ticks. J Virol. 2019;93(3):e01358-18. doi: 10.1128/JVI.01358-18, PMID 30404810.
30. Zivcec M, Safronetz D, Feldmann H. Animal models of tick-borne hemorrhagic fever viruses. Pathogens. 2013;2(2):402-21. doi: 10.3390/pathogens2020402, PMID 25437041.
31. Sakai M, Yoshii K, Sunden Y, Yokozawa K, Hirano M, Kariwa H. Variable region of the 3′ UTR is a critical virulence factor in the Far-Eastern subtype of tick-borne encephalitis virus in a mouse model. J Gen Virol. 2014;95(4):823-35. doi: 10.1099/vir.0.060046-0, PMID 24394696.
32. Fatmi SS, Zehra R, Carpenter DO. Powassan virus-a new reemerging tick-borne disease. Front Public Health. 2017;5:342. doi: 10.3389/fpubh.2017.00342, PMID 29312918.
33. Mans BJ, Featherston J, de Castro MH, Pienaar R. Gene duplication and protein evolution in tick-host interactions. rontiers in Cellular and Infection Microbiology. 2017;7:413. doi: 10.3389/fcimb.2017.00413, PMID 28993800.
34. Hall Mendelin S, Craig SB, Hall RA, O''Donoghue P, Atwell RB, Tulsiani SM. Tick paralysis in Australia caused by Ixodes holocyclus Neumann. Ann Trop Med Parasitol. 2011;105(2):95-0695-106. doi: 10.1179/136485911X12899838413628.
35. Golo PS, Angelo Ida Ida C, Camargo MG, Perinotto WM, Bittencourt VR. Effects of destruxin a on rhipicephalus (Boophilus) microplus ticks (Acari: Ixodidae). Rev Bras Parasitol Vet. 2011;20(4):338-41. doi: 10.1590/s1984-29612011000400015, PMID 22166391.
36. Tokarz R, Williams SH, Sameroff S, Sanchez Leon M, Jain K, Lipkin WI. Virome analysis of amblyomma americanum, Dermacentor variabilis, and Ixodes scapularis ticks reveals novel, highly divergent vertebrate and invertebrate viruses. Journal of Virology. 2014;88(19):11480-92. doi: 10.1128/JVI.01858-14, PMID 25056893.
37. Perveen N, Muzaffar SB, Al-Deeb MA. Ticks and tick-borne diseases of livestock in the middle East and North Africa: a review. Insects. 2021;12(1):83. doi: 10.3390/insects12010083, PMID 33477991.
38. Ferreri L, Giacobini M, Bajardi P, Rizzoli A, Rosa Ferreri L, Giacobini M, Bajardi P, Bertolotti L, Bolzoni L, Tagliapietra V. Pattern of tick aggregation on mice: larger than expected

distribution tail enhances the spread of tick-borne pathogens. PLoOS Comput Biol. 2014;10(11):e1003931. doi: 10.1371/journal.pcbi.1003931, PMID 25393293.

39. Dehhaghi M, Kazemi Shariat Panahi H, Holmes EC, Hudson BJ, Schloeffel R, Guillemin GJ. Human tick-borne diseases in Australia. Front Cell Infect Microbiol. 2019;9:3. doi: 10.3389/fcimb.2019.00003, PMID 30746341.
40. Sager H, Davis WC, Dobbelaere DA, Jungi TW. Macrophage-parasite relationship in theileriosis. Reversible phenotypic and functional dedifferentiation of macrophages infected with Theileria annulata. J Leukoc Biol. 1997;61(4):459-68. doi: 10.1002/jlb.61.4.459, PMID 9103233.
41. Sager H, Bertoni G, Jungi TW. Differences between B cell and macrophage transformation by the bovine parasite, Theileria annulata: a clonal approach. J Immunol. 1998;161(1):335-41. PMID 9647241.
42. Olds CL, Mason KL, Scoles GA. Rhipicephalus appendiculatus ticks transmit Theileria parva from persistently infected cattle in the absence of detectable parasitemia: implications for East Coast fever epidemiology. Parasit Vectors. 2018;11(1):126. doi: 10.1186/s13071-018-2727-6, PMID 29499743.
43. Norval RA, Lawrence JA, Young AS, Perry BD, Dolan TT, Scott J. Theileria parva: influence of vector, parasite and host relationships on the epidemiology of theileriosis in southern Africa. Parasitology. 1991;102(3):347-56. doi: 10.1017/s0031182000064295, PMID 1907728.
44. Bishop R, Musoke A, Morzaria S, Gardner M, Nene V. Theileria: intracellular protozoan parasites of wild and domestic ruminants transmitted by ixodid ticks. Parasitology. 2004;129Suppl:271-83S271-83. doi: 10.1017/s0031182003004748, PMID 15938515.
45. Nyabongo L, Odongo DO, Milton G, Machuka E, Vudriko P, Pelle R. Molecular survey of cattle ticks in Burundi: first report on the presence of the invasive Rhipicephalus microplus tick. PLoS One. 2021;16(12):e0261218. doi: 10.1371/journal.pone.0261218, PMID 34890445.
46. Eisen L. Pathogen transmission in relation to duration of attachment by Ixodes scapularis ticks. Ticks Tick Borne Dis. 2018;9(3):535-42. doi: 10.1016/j.ttbdis.2018.01.002, PMID 29398603.
47. Magnarelli LA, Williams SC, Norris SJ, Fikrig E. Serum antibodies to Borrelia burgdorferi, Anaplasma phagocytophilum, and Babesia microti in recaptured white-footed mice. J Wildl Dis. 2013;49(2):294-302. doi: 10.7589/2012-06-172, PMID 23568904.
48. Nuttall GHF. Ticks and tick-transmitted diseases. Trans Epidemiol Soc Lond. 1905;24:12-32. PMID 29419268.
49. Dantas Torres F. The brown dog tick, Rhipicephalus sanguineus (Latreille, 1806) (Acari: Ixodidae): from taxonomy to control. Vet Parasitol. 2008;152(3-4):173-85. doi: 10.1016/j.vetpar.2007.12.030, PMID 18280045.
50. Ruppin M, Sullivan S, Condon F, Perkins N, Lee L, Jeffcott LB. Retrospective study of 103 presumed cases of tick (Ixodes holocyclus) envenomation in the horse. Aust Vet J. 2012;90(5):175-80. doi: 10.1111/j.1751-0813.2012.00916.x. PMID 22510076.
51. Rochlin I, Toledo A. Emerging tick-borne pathogens of public health importance: a mini-review. J Med Microbiol. 2020;69(6):781-91. doi: 10.1099/jmm.0.001206, PMID 32478654.
52. Parola P, Raoult D. Ticks and tickborne bacterial diseases in humans: an emerging infectious threat. Clin Infect Dis. 2001;20032;(326):897-28897-928. doi: 10.1086/319347, PMID 11247714.
53. Marcelino I, Ventosa M, Pires E, Müller M, Lisacek F, Lefrançois T. Comparative proteomic profiling of hrlichia ruminantium pathogenic strain and its high-passaged attenuated strain reveals virulence and attenuation-associated proteins. PLoS One. 2015;10(12):e0145328. doi: 10.1371/journal. pone.0145328, PMID 26691135.
54. Noroy C, Meyer DF. Comparative genomics of the zoonotic pathogen ehrlichia chaffeensis reveals candidate type IV effectors and putative host cell targets host cell targets. Front Cell Infect Microbiol. 2017;6:204. doi: 10.3389/ fcimb.2016.00204.
55. Boyle WK, Wilder HK, Lawrence AM, Lopez JE. Transmission dynamics of Borrelia turicatae from the arthropod vector. PLoS Negl Trop Dis. 2014;8(4):e2767. doi: 10.1371/ journal.pntd.0002767, PMID 24699275.
56. Nelder MP, Russell CB, Sheehan NJ, Sander B, Moore S, Li Y. Human pathogens associated with the black-legged tick Ixodes scapularis: a systematic review. Parasit Vectors. 2016; 9:265. doi: 10.1186/s13071-016-1529-y, PMID 27151067.
57. Stanko M, Derdakova M, Spitalska E, Kazimirova M. Ticks and their epidemiological role in Slovakia: from the past till present. Biol (Bratisl). 2022;77(6):1575-610. doi: 10.1007/s11756-021-00845-3. PMID 34548672.
58. Maeda H, Hatta T, Alim MA, Tsubokawa D, Mikami F, Matsubayashi M. Establishment of a novel tick-Babesia experimental infection model. Sci Rep. 2016; 6:37039. doi: 10.1038/srep37039, PMID 27841321.
59. Chaudhuri S, Varshney JP, Patra RC. Erythrocytic antioxidant defense, lipid peroxides level and blood iron, zinc and copper concentrations in dogs naturally infected with Babesia gibsoni. Res Vet Sci. 2008;85(1):120-4. doi: 10.1016/j.rvsc.2007.09.001, PMID 18378268.
60. Saifee NH, Krause PJ, Wu Y. Apheresis for babesiosis: therapeutic parasite reduction or removal of harmful toxins or both?. J Clin Apheresis. 2016; (5)31(5):454-8. doi: 10.1002/jca.21429.
61. Eisen RJ, Kugeler KJ, Eisen L, Beard CB, Paddock CD. Tick-borne zoonoses in the United States: persistent and emerging threats to human health. ILAR J. 2017;58(3):319-35. doi: 10.1093/ilar/ilx005, PMID 28369515.
62. Karim S, Budachetri K, Mukherjee N, Williams J, Kausar A, Hassan MJ. A study of ticks and tick-borne livestock pathogens in Pakistan. PLoS Negl Trop Dis. 2017;11(6):e0005681. doi: 10.1371/journal.pntd.0005681, PMID 28650978.
63. Getange D, Bargul JL, Kanduma E, Collins M, Bodha B, Denge D. Ticks and tick-borne pathogens associated with dromedary camels (Camelus dromedarius) in Northern Kenya. Microorganisms. 2021;9(7);19. doi: 10.3390/microorganisms9071414, PMID 34209060.
64. Tahir D, Meyer L, Fourie J, Jongejan F, Mather T, Choumet V, Blagburn B, Straubinger RK, Varloud M. Interrupted blood feeding in ticks: causes and consequences. Microorganisms. 2020;8(6):910. doi: 10.3390/microorganisms8060910, PMID 32560202.
65. Onyiche TE, Raileanu C, Tauchmann O, Fischer S, Vasic A, Schafer M. Prevalence and molecular characterization of ticks and tick-borne pathogens of one-humped camels (Camelus dromedarius) in Nigeria. Parasit Vectors. 2020;13(1):428. doi: 10.1186/s13071-020-04272-2, PMID 32838795.
66. Ogata S, Mohamed WMA, Kusakisako K, Thu MJ, Qiu Y, Moustafa MAM, Mohamed WMA, Kusakisako K, Thu MJ. Spiroplasma infection among ixodid ticks exhibits species dependence and suggests a vertical pattern of transmission. Microorganisms. 2021;9(2):333. doi: 10.3390/microorganisms9020333, PMID 33567677.
67. Alberdi MP, Dalby MJ, Rodriguez Andres J, Fazakerley JK, Kohl A, Bell-Sakyi L. Detection and identification of putative bacterial endosymbionts and endogenous viruses in tick cell lines. Ticks Tick Borne Dis. 2012;3(3):137-46. doi: 10.1016/j.ttbdis.2012.05.002, PMID 22743047.
68. Portillo A, Palomar AM, de Toro M, Santibanez S, Santibanez P, Oteo JA. Exploring the bacteriome in anthropophilic ticks: to investigate the vectors for diagnosis. PLoS One. 2019;14(3):e0213384. doi: 10.1371/journal.pone.0213384, PMID 30889229.
69. Jongejan F, Su BL, Yang HJ, Berger L, Bevers J, Liu PC. Molecular evidence for the transovarial passage of Babesia gibsoni in Haemaphysalis hystricis (Acari: Ixodidae) ticks from Taiwan: a novel vector for canine babesiosis. Parasit Vectors. 2018; 11(1):134. doi: 10.1186/s13071-018-2722-y, PMID 29554924.
70. Molaei G, Little EAH, Stafford KC, Gaff H. A seven-legged tick: report of a morphological anomaly in Ixodes scapularis (Acari: Ixodidae) biting a human host from the Northeastern United

States. Ticks Tick Borne Dis. 2020;11(1):101304. doi: 10.1016/j.ttbdis.2019.101304, PMID 31564642.
71. Clifton DR, Rydkina E, Freeman RS, Sahni SK. NF-kappaB activation during rickettsia rickettsii infection of endothelial cells involves the activation of catalytic IkappaB kinases IKKalpha and IKKbeta and phosphorylation-proteolysis of the inhibitor protein Ikappa Balpha. Infect Immun. 2005;73(1):155-65. doi: 10.1128/IAI.73.1.155-165.2005, PMID 15618150.
72. Fox JG. Diseases transmitted by man's worst friend: the rat. Microbiol Spectr. 2015 Dec;3(6). doi: 10.1128/ microbiolspec.IOL5-0015-2015, PMID 27337284.
73. Gray JS, Kahl O, Lane RS, Levin ML, Tsao JI. Diapause in ticks of the medically important Ixodes ricinus species complex. Ticks Tick Borne Dis. 2016;7(5):992-003992-1003. doi: 10.1016/j.ttbdis.2016.05.006, PMID 27263092.
74. Sprong H, Azagi T, Hoornstra D, Nijhof AM, Knorr S, Baarsma ME, Hovius JW. Control of lyme borreliosis and other Ixodes ricinus-borne diseases. Parasit Vectors. 2018; 11(1):145. doi: 10.1186/s13071-018-2744-5, PMID 29510749.
75. Mohammad Saleh MS, Morsy ATA, Ismail MAM, Morsy TA. Tick-borne infectious diseases with reference to Egypt. J Egypt Soc Parasitol. 2016;46(2):273-98, PMID 30152938.
76. Kenedy MR, Lenhart TR, Akins DR. The role of Borrelia burgdorferi outer surface proteins. FEMS Immunol Med Microbiol. 2012;20(661):1-19. doi: 10.1111/j.1574-695X.2012.00980.x, PMID 22540535.
77. Lou Y, Wu J. Modeling Lyme disease transmission. Infect Dis Model 2017;2(2):229-43. doi: 10.1016/j.idm.2017.05.002, PMID 29928739.
78. Maaz D, Rausch S, Richter D, Krucken J, Kuhl AA, Demeler J, Blümke J. Susceptibility to ticks and Lyme disease spirochetes Iis not affected in mice coinfected with nematodes. Infect Immun. 2016;84(5):1274-86. doi: 10.1128/IAI.01309-15, PMID 26883594.
79. Jia N, Zheng YC, Ma L, Huo QB, Ni XB, Jiang BG. Human infections with Rickettsia raoultii, China. Emerg Infect Dis. 2014;20(5):866-8. doi: 10.3201/eid2005.130995. PMID 24750663.
80. Hart T, Yang X, Pal U, Lin YP. Identification of Lyme borreliae proteins promoting vertebrate host blood-specific spirochete survival in Ixodes scapularis nymphs using artificial feeding chambers. Ticks Tick Borne Dis. 2018;9(5):1057-63. doi: 10.1016/j.ttbdis.2018.03.033, PMID 29653905.
81. Kitsou C, Fikrig E, Pal U. Tick host immunity: vector immunomodulation and acquired tick resistance. Trends Immunol. 2021;42(7):554-74. doi: 10.1016/j.it.2021.05.005, PMID 34074602.
82. Hayes SF, Burgdorfer W, Aeschlimann A. Sexual transmission of spotted fever group rickettsiae by infected male ticks: detection of rickettsiae in immature spermatozoa of Ixodes ricinus. Infect Immun. 1980;27(2):638-42. doi: 10.1128/iai.27.2.638-642.1980, PMID 7380544.
83. Stokes JV, Moraru GM, McIntosh C, Kummari E, Rausch K, Varela-Stokes AS. Differentiated THP-1 cells exposed to pathogenic and nonpathogenic Borrelia species demonstrate minimal differences in production of four inflammatory cytokines. Vector Borne Zoonotic Dis. 2016;16(11):691-5. doi: 10.1089/vbz.2016.2006, PMID 27680384.
84. Hu E, Meng Y, Ma Y, Song R, Hu Z, Li M. De novo assembly and analysis of the transcriptome of the dermacentor marginatus genes differentially expressed after blood-feeding and long-term starvation. Parasit Vectors. 2020;13(1):563. doi: 10.1186/s13071-020-04442-2, PMID 33172483.
85. Gerhart JG, Auguste Dutcher H, Brenner AE, Moses AS, Grubhoffer L, Raghavan R. Multiple acquisitions of pathogen-derived rancisella endosymbionts in soft ticks. Genome Biol Evol. 2018;10(2):607-15. doi: 10.1093/gbe/evy021, PMID 29385445.
86. Yoder JA, Benoit JB, Denlinger DL, Tank JL, Zettler LW. An endosymbiotic conidial fungus, Scopulariopsis brevicaulis, protects the American dog tick, Dermacentor variabilis, from desiccation imposed by an entomopathogenic fungus. J Invertebr Pathol. 2008;97(2):119-27. doi: 10.1016/j.jip.2007.07.011, PMID 17880996.
87. Moses AS, Millar JA, Bonazzi M, Beare PA, Raghavan R. Horizontally acquired biosynthesis genes boost Coxiella burnetii''s physiology. Front Cell Infect Microbiol. 2017;7:174. doi: 10.3389/fcimb.2017.00174, PMID 28540258.
88. Felsheim RF, Chávez AS, Palmer GH, Crosby L, Barbet AF, Kurtti TJ. Transformation of Anaplasma marginale. Vet Parasitol. 2010;167(2-4):167-74. doi: 10.1016/j.vetpar.2009.09.018, PMID 19837516.
89. Moriello KA. Zoonotic skin diseases of dogs and cats. Anim Health Res Rev. 2003;4(2):157-68. doi: 10.1079/ahr200355, PMID 15134297.
90. Mohammadi F, Hashemi SJ, Zoll J, Melchers WJ, Rafati H, Dehghan P. Quantitative analysis of single-nucleotide polymorphism for rapid detection of TR34/L98H-and TR46/Y121F/T289A-positive aspergillus fumigatus isolates obtained from patients in Iran from 2010 to 2014. Antimicrob Agents Chemother 2016;60(1):387-92. doi: 10.1128/AAC.02326-15. PMID 26525787.
91. Brites Neto J, Duarte KM, Martins TF. Tick-borne infections in human and animal population worldwide. Vet World. 2015;8(3):301-15. doi: 10.14202/vetworld.2015.301-315, PMID 27047089.
92. Bernardo CC, Barreto LP, Silva EC, Arruda W, Fernandes EKK. Conidia and blastospores of metarhizium spp. and Beauveria bassianas. CSR, (Luz). Their development during the infection process and virulence against the tick Rhipicephalus microplus. Ticks Tick Borne Dis 2018;1:1334-42.
93. Francischetti IM, Mans BJ, Meng Z, Gudderra N, Veenstra TD, Pham VM. An insight into the sialome of the soft tick, Ornithodorus parkeri:. Insect Biochem Mol Biol. 2008;38(1):1-21. doi: 10.1016/j.ibmb.2007.09.009, PMID 18070662.
94. Greay TL, Gofton AW, Paparini A, Ryan UM, Oskam CL, Irwin PJ. Recent insights into the tick microbiome gained through next-generation sequencing. Parasites Vectors. 2018;11(1):12. doi: 10.1186/s13071-017-2550-5, PMID 29301588.
95. Fogaça AC, Sousa G, Pavanelo DB, Esteves E, Martins LA, Urbanova V. Tick immune system: what is known, the interconnections, the gaps, and the challenges. Front Immunol. 2021;12:628054. doi: 10.3389/fimmu.2021.628054, PMID 33737931.
96. Oleaga A, Carnero Moran A, Valero ML, Perez Sanchez R. Proteomics informed by transcriptomics for a qualitative and quantitative analysis of the sialoproteome of adult Ornithodoros moubataticks. Parasit Vectors. 2021;14(1):396. doi: 10.1186/s13071-021-04892-2, PMID 34380568.
97. Aounallah H, Bensaoud C, M''ghirbi Y, Faria F, Chmelar JI, Kotsyfakis M. Tick salivary compounds for targeted immunomodulatory therapy. Front Immunol. 2020;11:583845. doi: 10.3389/fimmu.2020.583845, PMID 33072132.
98. Giachetto PF, Cunha RC, Nhani A, Garcia MV, Ferro JA, Andreotti R. Gene expression in the salivary gland of rhipicephalus (Boophilus) microplus Fed on tick-susceptible and tick-resistant hosts. Front Cell Infect Microbiol. 2019;9:477. doi: 10.3389/fcimb.2019.00477. PMID 32039052.
99. Klaus C, Ziegler U, Kalthoff D, Hoffmann B, Beer M. Tick-borne encephalitis virus (TBEV)– findings on cross-reactivity and longevity of TBEV antibodies in animal sera. BMC Vet Res. 2014;10:78. doi: 10.1186/1746-6148-10-78, PMID 24690234.
100. Klaus C, Beer M, Saier R, Schau U, Moog U, Hoffmann B. Goats and sheep as sentinels for tick-borne encephalitis (TBE) virus-epidemiological studies in areas endemic and non-endemic for TBE virus in Germany Dis. Ticks Tick Borne Dis. 2012; 3(1):27-37. doi: 10.1016/j.ttbdis.2011.09.011, PMID 22309856.
101. Bullard R, Allen P, Chao CC, Douglas J, Das P, Morgan SE. Structural characterization of tick cement cones collected from *in vivo* and artificial membrane blood-fed Lone Star ticks (Amblyomma americanum). Ticks Tick Borne Dis. 2016;7(5):880-92. doi: 10.1016/j.ttbdis.2016.04.006, PMID 27118479.
102. Hoffmann A, Muller T, Fingerle V, Noll M. Presence of Human pathogens of the borrelia burgdorferi sensu lato complex shifts the sequence read abundances of tick microbiomes in two german locations. Microorganisms. 2021;9(9):1814. doi: 10.3390/microorganisms9091814, PMID 34576710.

103. Nakao R, Qiu Y, Igarashi M, Magona JW, Zhou L, Ito K, Sugimoto C. High prevalence of spotted fever group rickettsiae in Amblyomma variegatum from Uganda and their identification using sizes of intergenic spacers. Ticks Tick Borne Dis. 2013;64(6):506-12. doi: 10.1016/j.ttbdis.2013.07.001, PMID 24331642.
104. Taya Y, Kinoshita G, Mohamed WMA, Moustafa MAM, Ogata S, Chatanga E, Mohamed WMA, Moustafa MAM, Ogata S. Applications of blocker nucleic acids and non-metazoan PCR improves the discovery of the eukaryotic microbiome in ticks. Microorganisms. 2021;9(5):1051. doi: 10.3390/microorganisms9051051, PMID 34068298.
105. Stefanoff P, Pfeffer M, Hellenbrand W, Rogalska J, Ruhe F, Makówka A. Virus detection in questing ticks is not a sensitive indicator for risk assessment of tick-borne encephalitis in humans. Zoonoses Public Health. 2013 May;60(3):215-26. doi: 10.1111/j.1863-2378.2012.01517.x, PMID 22765504.
106. Pugliese A, Beltramo T, Torre D. Seroprevalence study of tick-borne encephalitis, Borrelia burgdorferi, Dengue and toscana virus in turin province. Cell Biochem Funct. 2007;(2);25(2):185-8. doi: 10.1002/cbf.1302, PMID 16312014.
107. Gustafson R. Epidemiological studies of Lyme borreliosis and tick-borne encephalitis. Scand J Infect Dis Suppl. 1994; 92:1-63. PMID 8047853.
108. Pugliese A, Beltramo T, Torre D. Seroprevalence study of Tick-borne encephalitis, Borrelia burgdorferi, Dengue and toscana virus in turin province. Cell Biochem Funct. 2007;25(2):185-8. doi: 10.1002/cbf.1302, PMID 16312014.
109. Lebech AM. Polymerase chain reaction in diagnosis of Borrelia burgdorferi infections and studies on taxonomic classification. APMIS Suppl. 2002;105(105):1-40. PMID 11985118.
110. Lebech AM, Hansen K, Brandrup F, Clemmensen O, Halkier Sørensen L. Diagnostic value of PCR for detection of Borrelia burgdorferi DNA in clinical specimens from patients with erythema migrans and Lyme neuroborreliosis. Mol Diagn. 2000;5(2):139-50. doi: 10.1007/BF03262032, PMID 11066015.
111. Sambri V, Marangoni A, Storni E, Cavrini F, Moroni A, Sparacino M. Tick borne zoonosis: selected clinical and diagnostic aspects. Parassitologia. 2004;46(1-2):109-13. PMID 15305697.
112. Stunzner D, Pierer K, Hubalek Z, Halouzka J, Aberer E, Millner MM. Species identification of Borrelia burgdorferi sensu lato from tick and human isolates in Styria (Austria) by PCR-RFLP analysis. Wien Klin Wochenschr. 1999;111(22-23):994-6. PMID 10666817.
113. Binetruy F, Chevillon C, de Thoisy B, Garnier S, Duron O. Survey of ticks in French Guiana. Ticks Tick Borne Dis. 2019;10(1):77-85. doi: 10.1016/j.ttbdis.2018.09.003, PMID 30224310.
114. Stone BL, Russart NM, Gaultney RA, Floden AM, Vaughan JA, Brissette CA. The Western progression of lyme disease: infectious and nonclonal Borrelia burgdorferi Sensu Lato populations in Grand Forks County, North Dakota. Appl Environ Microbiol. 2015;81(1):48-58. doi: 10.1128/AEM.02422-14, PMID 25304515.
115. Cisak E, Wojcik Fatla A, Stojek N, Chmielewska Badora J, Zwolinski J, Buczek A. Prevalence of Borrelia burgdorferi genospecies in Ixodes ricinus ticks from Lublin region (eastern Poland). Ann Agric Environ Med. 2006;13(2):301-6. PMID 17196005.
116. Wodecka B, Sawczuk M. Occurence of pathogenic genospecies of Borrelia burgdorferi sensu lato in Ixodes ricinus ticks collected from north-western Poland Borrelia burgdorferi sensu lato w kleszczach Ixodes ricinus odławianych z północno-zachodniej polski [Occurence of pathogenic genospecies of Borrelia burgdorferi sensu lato in Ixodes ricinus ticks collected from north-western Poland. Wiad Parazytol. 2004;50(3):545-53. PMID 16865967.
117. Kumsa B, Socolovschi C, Almeras L, Raoult D, Parola P. Occurrence and ggenotyping of coxiella burnetii in ixodid ticks in Oromia, Ethiopia. Am J Trop Med Hyg. 2015;93(5):1074-81. doi: 10.4269/ajtmh.14-0758, PMID 26392155.
118. Gooskens J, Templeton KE, Claas EC, van Dam AP. Evaluation of an internally controlled real-time PCR targeting the ospA gene for detection of Borrelia burgdorferi sensu lato DNA in cerebrospinal fluid. Clin Microbiol Infect. 2006;12(9):894-900. doi: 10.1111/j.1469-0691.2006.01509.x, PMID 16882295.
119. Stanek G, Reiter M. The expanding lyme borrelia complex-clinical significance of genomic species? Clin Microbiol Infect. 2011;17(4):487-93. doi: 10.1111/j.1469-0691.2011.03492.x, PMID 21414082.
120. Trinachartvanit W, Hirunkanokpun S, Sudsangiem R, Lijuan W, Boonkusol D, Baimai V. Borrelia sp. phylogenetically different from Lyme disease- and relapsing fever-related Borrelia spp. in Amblyomma varanense from Python reticulatus. Parasit Vectors. 2016;9(1):359. doi: 10.1186/s13071-016-1629-8, PMID 27342652.
121. Fischhoff IR, Keesing F, Ostfeld RS. Risk factors for bites and diseases associated with black-legged ticks: A meta-analysis. Am J Epidemiol. 2019;188(9):501742-50. doi: 10.1093/aje/kwz130, PMID 31145773.
122. Lorusso V, Otranto D, Jongejan F, Welburn SC, Picozzi K, Lorusso V, Wijnveld M, Latrofa MS, Fajinmi A, Majekodunmi AO, Dogo AG. Canine and ovine tick-borne pathogens in camels, Nigeria. Vet Parasitol. 2016;228:90-92. doi: 10.1016/j.vetpar.2016.08.014, PMID 27692338.
123. Carr AL, Roe M. Acarine attractants: chemoreception, bioassay, chemistry and control. Pestic Biochem Physiol. 2016;131:60-79. doi: 10.1016/j.pestbp.2015.12.009, PMID 27265828.
124. Tahir D, Asri B, Meyer LN, Evans A, Mather T, Blagburn B. Vectra 3D (dinotefuran, pyriproxyfen and permethrin) prevents acquisition of Borrelia burgdorferi sensu stricto by Ixodes ricinus and Ixodes scapularis ticks in an ex vivo feeding model. Parasit Vectors. 2021;14(1):416. doi: 10.1186/s13071-021-04881-5, PMID 34419129.
125. Neelakanta G, Sultana H. Transmission-blocking vaccines: focus on anti-vector vaccines against tick-borne diseases. Arch Immunol Ther Exp (Warsz). 2015;63(3):169-79. doi: 10.1007/s00005-014-0324-8, PMID 25503555.
126. Porter LM, Radulovic ZM, Mulenga A. A repertoire of protease inhibitor families in Amblyomma americanum and other tick species: inter-species comparative analyses. Parasit Vectors. 2017;10(1):152. doi: 10.1186/s13071-017-2080-1, PMID 28330502.
127. Bonnet SI, Binetruy F, Hernandez Jarguin AM, Duron O. The tick microbiome: why non-pathogenic microorganisms matter in tick biology and pathogen transmission. Front Cell Infect Microbiol. 2017;7:236. doi: 10.3389/fcimb.2017.00236, PMID 28642842.
128. Rego ROM, Trentelman JJA, Anguita J, Nijhof AM, Sprong H, Klempa B. Counterattacking the tick bite: towards a rational design of anti-tick vaccines targeting pathogen transmission. Parasit Vectors. 2019;12(1):229. doi: 10.1186/s13071-019-3468-x, PMID 31088506.
129. Rodriguez Vivas RI, Jonsson NN, Bhushan C. Strategies for the control of Rhipicephalus microplus ticks in a world of conventional acaricide and macrocyclic lactone resistance. Parasitol Res. 2018;117(1):3-29. doi: 10.1007/s00436-017-5677-6, PMID 29152691.
130. Kumar B, Manjunathachar HV, Ghosh S. A review on hyalomma species infestations on human and animals and progress on management strategies. Heliyon. 2020;6(12):e05675. doi: 10.1016/j.heliyon.2020.e05675, PMID 33319114.
131. Eisen L. Vector competence studies with hard ticks and Borrelia burgdorferi sensu lato spirochetes: a review. Ticks Tick Borne Dis. 2020;11(3):101359. doi: 10.1016/j.ttbdis.2019.101359, PMID 32067949.
132. Yadav N, Upadhyay RK. "Tick saliva toxins, host immune responses and its biological effects". International Journal of Pharmacy and Pharmaceutical Sciences. 2021;13:9-19. doi: 10.22159/ijpps.2021v13i8.41444.
133. Preet P. Peptides: a new therapeutic approach. Int J Curr Pharm Sci. 2018;10(2):29-34. doi: 10.22159/ijcpr.2018v10i2.25887.