

Review Article

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Drivers for the Emergence of Tickborne Zoonoses

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ABSTRACT

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Zoonotic diseases constitute a unique group of infectious diseases that affect humans as well as animals. About 73 per cent of emerging infectious pathogens are of zoonotic origin. Ticks are the major vectors involved in the dissemination of many infectious pathogens, responsible for human and animal diseases. In India, ticks and tickborne diseases have been implicated to cause projected loss of USD \$500 million per year. Numerous wild and domestic animals are considered as reservoirs for tickborne infections in livestock, pet animals and humans. The accelerating appearance of zoonoses via ticks is a serious global public health threat, due to its morbidity and mortality in humans. Over the past three decades, vector-borne infectious agents have been on the move, initiating contemporary challenges for public health. There are three important drivers, namely anthropic, ecological and climatic which are responsible for rise in tick borne zoonoses. Reducing the risk factors will be the effective step in preventing the diseases. Understanding the evolutionary relationships between mechanical vectors, use of chemicals to manage ticks, wide spread usage of anti-tick vaccine will help to alleviate the effects of tick borne zoonoses. One Health approach for better management of emerging tick borne zoonotic diseases may be widely adopted.

Introduction

Zoonotic diseases constitute a unique group of infectious diseases that affect humans as well as animals. The term zoonoses are defined as “Diseases and infections which are naturally transmitted between vertebrate animals and humans” (WHO, 2006). Among 1415 human pathogens, 61 per cent are zoonotic in nature. About 73 per cent of emerging infectious pathogens are of zoonotic origin (Taylor *et al.*, 2001). The emerging zoonoses are diseases newly recognized or

newly evolved or that has occurred previously but shows an increase in incidence or expansion in geographical, host or vector range (Taylor *et al.*, 2001) due to their changing ecology (Dhiman, 2014). Ticks are the major vectors involved in the dissemination of many infectious pathogens, responsible for human and animal diseases (Sonenshine, 1991). Betancourt (2017) stated that the losses caused by the tick infestation, the associated diseases and the control of it, have been calculated at USD \$13.9–18.7 billion annually worldwide. In India alone,

ticks and tickborne diseases have been implicated to cause projected loss of USD \$500 million per year (Ghosh *et al.*, 2007). Numerous wild and domestic animals are considered as reservoirs for tickborne infections in livestock, pet animals and humans (Jongejan and Uilenberg, 2004). Hard ticks contribute to the 80 per cent of the global tick population and the remaining 20 per cent are soft ticks. However, only ten per cent of the tick species are known to be involved in transmission of diseases to animals and humans (Parola and Raoult, 2001). The accelerating appearance of zoonoses via ticks is a serious global public health threat, due to its morbidity and mortality in humans (Vesco *et al.*, 2010). In this current review it is intended to focus on the drivers that are responsible for the transmission of tickborne zoonoses are discussed.

Classification of ticks

Ticks are arthropods belong to the phylum Arthropoda and the class Arachnid. They are diverse in nature with nine hundred different species, which comes under taxonomical families, the Argasidae (Softtick), Ixodidae (Hardticks) and Nuttalliellidae (Guglielmone *et al.*, 2010).

Drivers for emergence of tickborne zoonoses

The events or conditions (drivers) that result in the cross-over of an animal pathogen into humans are not well characterised, but emergence is generally hastened by modifications to ecological or biological systems (Wilcox and Colwell, 2005). Over the past three decades, vector-borne infectious agents have been on the move, initiating contemporary challenges for public health (Weaver and Reisen, 2010). Globally, past 30 years, the numbers of different and

epidemiologically crucial diseases are recognized as tick-borne pathogens (Estrada-Peña *et al.*, 2012). Zoonotic diseases transmitted through ticks around the globe are illustrated in Table 1. The most important drivers responsible for the emergence of tickborne zoonoses are anthropic, ecological and climatic drivers are discussed below.

Anthropic drivers

Rapid explosion of population coupled with globalisation and demographic changes increase the human-environment interaction, which points the way how anthropic (humans) drivers impacts the emergence of tick borne zoonotic diseases. Humans are not crucial reservoirs for tickborne zoonoses, although ticks can possibly cause illnesses in numerous peoples, such events which typically pre disposes humans are accidents (Baneth, 2014). The global population is projected to rise by 32 per cent with the period of 2011-2050 and the increase will be mainly focused in urban areas of developing nations (UN-DESA, 2012). So, the demand for food in urban areas will also rise and result in animal and their products being transported over very huge distances from a wider catchment area and thereby increase risk of dissemination of emerging diseases (Janes *et al.*, 2012). In recent years, the population of humans is growing and expanding in new landscapes with the use of soil, encroachment into wildlife habitat which opens the door for transmission of pathogens to humans (Cabello and Cabello, 2008).

The emergence of tickborne zoonoses is associated with modification in the use of the land, which obligate agents and ticks vectors to find novel transmission mode associated with humans. Furthermore, social-economic conditions of the human population also encourage the emergence of tickborne zoonoses. The risk is higher among wealthy

and poverty than those of the middle-class peoples. For example, people with higher earnings look for country homes near forests (Kilpatrick *et al.*, 2012) and they have the activity of travel to formerly inaccessible places. Moreover, the habit of outdoor activities such as trekking and camping has increased (Mansfield *et al.*, 2009). On the

other side, low-income peoples can be less immune against pathogens because of malnutrition or immune suppression and gaining to in-stock vaccines for some zoonotic agent transmitted by ticks, which are usually costly, is limited (Godfrey and Randolph, 2011).

Table.1 Zoonotic diseases transmitted through ticks

Zoonotic Diseases	Causative agent	Vectors	References
Babesiosis	<i>Babesia microti</i> ; <i>B. divergens</i>	<i>Ixodes scapularis</i> <i>Ixodes ricinus</i>	Wormser <i>et al.</i> , (2006); Gray <i>et al.</i> , (2010)
Colorado tick fever	Colti virus	<i>Dermacentor andersoni</i>	Piesman and Eisen, (2008); Brackney <i>et al.</i> , (2010)
Crimean-Congo haemorrhagic fever	Nairo virus	<i>Hyalomma marginatum</i>	Ergonul, (2006)
Human granulocytic anaplasmosis	<i>Anaplasma phagocytophilum</i>	<i>Ixodes scapularis</i> , <i>Ixodes pacificus</i> , <i>Ixodes persulcatus</i> , <i>Ixodes ricinus</i>	Wormser <i>et al.</i> , (2006)
Human Monocytic Ehrlichiosis	<i>Ehrlichia canis</i>	<i>Rhipicephalus sanguineus</i>	Ndip <i>et al.</i> , (2007)
Indian tick typhus	<i>Rickettsia conorii</i> subsp. <i>indica</i>	<i>Rhipicephalus sanguineus</i>	Sentausa <i>et al.</i> , (2012)
Kyasanur forest disease	Flavi virus	<i>Haemaphysalis spinigera</i>	Dobler, (2010)
Langat Virus	Flavi virus	<i>Ixodesgranulatus</i> , <i>I. persulcatus</i> ; <i>Haemaphysalis papuana</i>	Dobler, (2010)
Lyme disease	<i>Borrelia burgdorferi</i>	<i>Ixodes spp.</i>	Wormser <i>et al.</i> , (2006)
Powassan encephalitis	Flavi virus	<i>Ixodes spp.</i>	Dobler, (2010)
Q Fever	<i>Coxiella burnetii</i>	More than 40 species of <i>Haemaphysalis spp.</i> , and <i>Ixodes spp.</i> , (Europe) and <i>Rhipicephalus spp.</i> , <i>Amblyomma spp.</i> , and <i>Dermacentor</i> <i>spp.</i> , of (America)	Piesman and Eisen, (2008); Contreras <i>et al.</i> , (2013)
Relapsing fever	<i>Borrelia spp.</i>	<i>Ornithodoros spp.</i>	Piesman and Eisen, (2008)
Rocky Mountain spotted fever	<i>Rickettsia rickettsii</i>	<i>Amblyomma cajennense</i> , <i>Dermacentor andersoni</i> , <i>Dermacentor variabilis</i> , <i>Rhipicephalus sanguineus</i>	Fritz, (2009); Piesman and Eisen, (2008)
Thrombocytopenia syndrome with severe fever	Phlebo virus	<i>Haemaphysalis longicornis</i>	Liu <i>et al.</i> , (2014)
Tick-borne African fever	<i>Rickettsia africae</i>	<i>Amblyomma hebraeum</i> , <i>Amblyomma variegatum</i>	Piesman and Eisen, (2008); Althaus <i>et al.</i> , (2010)
Tick-borne encephalitis	Flavi virus	<i>Ixodes spp.</i> (<i>I. ricinus</i> ; <i>I. persulcatus</i>)	Dobler, (2010); Piesman and Eisen, (2008)
Tularemia	<i>Francisella tularensis</i>	<i>Dermacentor andersonii</i> , <i>D.</i> <i>variabilis</i> , <i>D. occidentalis</i> and <i>Amblyommaamericanum</i>	Fritz, (2009)

Ecological drivers

The millennium ecosystem assessment describes ecological driver as any natural or human induced factor that directly or indirectly causes a change in an ecosystem (Carpenter *et al.*, 2006). Interference in the circulation among animals, wild reservoirs and ticks contribute to the appearance of tickborne pathogens (Baneth, 2014). Even though wild animals are principle reservoirs for numerous pathogenic agents that reproduce infection in humans, domestic animals can eventually become important reservoirs for some tickborne zoonotic agents (Dantas-Torres *et al.*, 2012). Reforestation activity during the period of 20th century in northeastern North America is thought to have allowed recolonisation by deer and the subsequent expansion of the range of *Ixodes scapularis*, reinforcing the emergence of Lyme disease (Barbour and Fish, 1993). The displacement of ticks is very limited and without the assistance of a vertebrate mechanical vector, cannot be moved over great distances with which ticks traverse natural boundaries and be dispersed over high altitude terrains, islands and water bodies (Mills *et al.*, 2014). When mechanical vectors are introduced by human populations in a new geographical area, ticks colonise that zones (Baneth, 2014). The hosts that tend to have dense population and rapid life cycles are most capable natural reservoirs for some tickborne pathogens (Ostfeld *et al.*, 2014) such as rodent and birds (Halos *et al.*, 2010). Birds alone account for approximately fifty per cent of animals that host ticks and tickborne pathogens (De la Fuente *et al.*, 2015). So, birds are crucial components of the ecological networks between host, ticks and pathogens since, immature and adult stages are mostly found on wild birds (Owen *et al.*, 2010). Birds have high epidemiological importance because they have a great flight distance in a span of few days (Hornok *et al.*,

2014). The epidemiologic potential is higher because of horizontal transmission of tickborne zoonotic agents between birds that share the same ecological niches (Palomar *et al.*, 2012). The increase in interaction between wild and domestic animals contributes a higher level of transmission of ticks to humans (Liyanaarachchi *et al.*, 2015).

Climatic drivers

Climate change is a long-term shift in global or regional climate patterns. Climate change often refers specifically to the rise in global temperatures from the mid-20th century to present (NGS, 2019). Greenhouse gases are the major human-influenced drivers of climate change. These gases warm the earth's surface by trapping heat in the atmosphere (OEHHA, 2018). Climate change impact wellbeing and human health in numerous ways by ease the dissemination of numerous pathogenic agents (Colwell *et al.*, 2011). Several blood-feeding vectors such as ticks confer most of their life cycle in the environment and their development, survival and population dynamics depend on various factors which includes host availability, vegetation coverage and climate (Randolph, 2009; Dantas-Torres, 2010). Development rates of ticks increase with the rise of temperature (Randolph, 2008). The high temperatures give rise to three fundamental aspects of vectors: bite rate, development rate and the rate of pathogenic agent replication (Kilpatrick and Randolph, 2012). Climate change may affect tick dissemination and density as well as the risk of pathogen transmission to humans (Leger *et al.*, 2013). The effect of climate change (rise in temperatures) in tropical regions may be destructive to little number of species, particularly affecting habitat suitability. This can promote the migration of vertebrate hosts, which contributes the spread of ticks and pathogens to new territories (Baneth, 2014)

due to weather changes, these new areas can be transformed into favourable habitats for ticks (Fritz, 2009). Both temperature and humidity influence the behaviour, survival and reproduction of numerous species of vectors (Mills *et al.*, 2010). Moreover, prolonged periods of higher temperature and low humidity can disturb the enzootic cycle of some tickborne pathogens (Eg: Tick-borne encephalitis) (Burri *et al.*, 2011). A study regarding the influence of climate change on tickborne disease by Parola *et al.* (2008) correlated a cluster of Mediterranean spotted fever cases to a warming-mediated increase in the aggressiveness of *Rhipicephalus sanguineus* Latreille (brown dog ticks). Climate change has been implicated as a critical driving force for the expansion of the *Ixodes persulcatus* (taiga tick) habitat and the incidence of tickborne encephalitis in the north of European Russia (Tokarevich *et al.*, 2011). Earth's natural system is transforming due to the development of human race, but the health effect of ecosystem alteration is still poorly understood (Myers *et al.*, 2013).

In conclusion tickborne zoonotic diseases are of serious public health threat around the world. Reducing the risk factors will be the effective step in preventing the diseases. It is also critical to consider the evolutionary relationships between mechanical vectors like birds, ticks and transmitted pathogens. Personal care by avoiding roaming in grassy areas, wearing long-sleeved shirts, performing daily tick checks or with the use of chemicals such as DEET (N, N-Diethyl-m-toluamide) or by application of biological measures such as insectivorous mammals and birds (white-footed mice and guinea fowl), parasitoid wasps and flies tick infestation can be controlled. Moreover, Anti-tick vaccines are available for the controlling of tickborne diseases and protecting humans and livestock from pathogenic tickborne agents. One Health is the collaborative effort of various health

science sectors to attain excellent health for human, domestic animals, wildlife and our environment. Hence, there is a strong need for a One Health approach for better management of emerging tickborne zoonotic diseases.

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