Ticks (Arachnida: Acari) induced Paralysis in Humans and Control of Incidence in the Current Civilization

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Abstract

Worldwide, ticks and tick-borne diseases are of major significance both as factors directly influencing human health and also as factors reducing potential protein production where they dramatically reduce the health of domestic animals. In some areas, the significance of ticks is well known and a lot of efforts have gone into characterizing the diseases which they transmit. Tick borne diseases, tick paralysis and severe allergic reactions can pose serious health threat. Tick borne paralysis is an acute, ascending motor paralysis which can often end being fatal for the victim (both humans and animals), especially if the tick is not located and removed immediately. The causative agent of such paralysis is the toxin (neurotoxin) called Holocyclotoxin in the tick’s saliva. In this publication it is hoped to give some background on the human tick-borne paralysis that is a loss of muscle function which results from a tick bite and its treatment. Globally, the most common culprits associated with tick paralysis are Dermacentor variabilis (American dog tick) and Dermacentor andersoni (Rocky Mountain wood tick), but bites from Amblyomma and Ixodes ticks can also cause tick paralysis. A person can be exposed to ticks in some way, for example, may has been on a recent camping trip, live in a tick-infested area, or have dogs or other animals that can pick up ticks. Hard and soft-bodied female ticks are believed to make a poison that can cause paralysis especially in children. Ticks attach to the skin of victim to feed on blood and it is during this feeding process that the toxin enters the bloodstream. Ticks injected toxins inflict local irritation or mild irritation, however most tick bites cause little or no symptoms. Clinical features of tick bite paralysis are restlessness in the bitten human; weakness in lower limbs which starts spreading, victim might fall down, and show in-coordination and cranial nerve weakness. In children, apart from restlessness and irritability, there may be vomiting, anorexia, malaise and the symptoms that can often turn fatal. The paralysis is ascending that means it starts in the lower body and moves up side. It is similar to that seen in Guillain-Barre syndrome and opposite that seen in botulism and paralytic shellfish poisoning. Children with tick paralysis develop an unsteady gait (ataxia) followed several days later by weakness in the lower legs that gradually moves up to involve the upper limbs. Paralysis may cause breathing difficulties, which may require the use of a breathing machine and the child may also have mild, flu-like symptoms (muscle aches, tiredness). If child suddenly becomes unsteady or weak, have the child examined promptly and breathing difficulties require emergency care by medical professional. Often the tick is found only after thoroughly searching the person's hair or finding a tick embedded in the skin and noting of symptoms confirms the diagnosis. Removing the tick can eliminate the source of the neurotoxin and recovery is expected or rapid following the removal of the tick. Use insect repellents and protective clothing when out in tick-infested areas, carefully check the skin after being outside and remove any ticks if attached to body.

Keywords: Tick Paralysis, Neurological Disorders, Neurotoxin Poisonings, Tick Removal
1. Introduction

Ticks are parasites that feed on the animal and human blood, and these occur in humid and moist bushy areas. They are not very mobile but rely on passing animals to both feed on and transport to them. Ticks classified under class Arachnida are of two types; hard ticks (family Ixodidae) and soft ticks (family Argasidae). Hard ticks have a scutum or dorsal shield, while soft ticks do not have shield. In males hard ticks, the scutum completely covers the dorsal surface while in females the scutum covers only the anterior portion of the dorsal surface. The capitulum of hard ticks is visible or extends forward from the anterior end of the body. In soft ticks, the capitulum is found on the ventral side, does not extend beyond the anterior margin of the body and is usually not visible from a dorsal view of the tick. Male and female soft ticks are similar in appearance and lack a scutum or dorsal shield which can be used to distinguish the sexes in hard ticks. Some species of soft ticks do feed on humans, but are more commonly found on birds and small mammals. There are no tick species within the Argasidae or soft tick species family which can transmit tick-borne diseases of concern to humans. The soft ticks are represented by only a few species and often associated with nests or resting places of animals and these ticks have a wrinkled appearance which is similar to soft leather. The ticks of most importance to humans and domestic animals are member of the family Ixodidae (Varma, 1993; Cilek and Olson, 2000).

2. Human Tick Paralysis

Tick paralysis results from exposure to a neurotoxin released by tick salivary glands during a blood meal and it is the only tick-borne disease not caused by an infectious agent. The toxin appears to be produced exclusively by female, egg-laden ticks. It is most commonly seen in children lower than 16 years, and within this population it affects girls more than boys, probably because ticks are harder to detect under longer hair, and among adults, men are disproportionately affected. Worldwide, over 40 tick species have been associated with tick paralysis, but the most common culprits are Dermacentor variabilis (American dog tick) and Dermacentor andersoni (Rocky Mountain wood tick). Bites from Amblyomma and Ixodes ticks can also cause tick paralysis (Kinzer et al., 1990). In humans, tick paralysis is most likely to be seen in children. The symptoms in humans are similar to the clinical signs in dogs. About two thirds of human cases are seen in young females. The tick bites are most often found at the head and there at the transition of hair and neck. The clinical presentation appears as typical ascending flaccid paralysis. After aprodromal phase (paraesthesias, restlessness, irritability, fatigue and myalgias) neurological symptoms will start with paralysis of the lower extremities. The deep tendon reflexes are weak or absent and during the next 12 to 24 hours the muscles innervated by facial nerves become weak. Without removal of the tick, finally the respiratory muscles will fail and the patient may die of respiratory failure. Rare forms of illness include focal muscles paralysis (facial muscles, arm muscles, pupillary dilation and acute cerebellar syndrome). Sensory findings are generally absent and therefore form an important differential diagnostic symptom to the Guillain-Barre syndrome where sensory findings are frequently found during the prodromal stage of disease (Malik and Farrow, 1991; Gordon and Giza, 2004).

3. Signs and Symptoms Tick Paralysis
Tick paralysis results from inoculation of a toxin from tick salivary glands during a blood meal. Typically, symptoms in humans appear within 2-6 days of tick attachment. Early symptoms of tick paralysis can include rashes, headache, fever, flu-like symptoms, tenderness of lymph nodes, unsteady gait, intolerance to bright light, increased weakness of the limbs and partial facial paralysis. As the tick engorges on more human blood, the tick paralysis symptoms may intensify following the tick has been removed. Clinical diagnosis is also confirmed by specific blood tests. In some susceptible people, tick bite may cause a severe allergic reaction or anaphylactic shock, which can be life-threatening. If swelling of the face and throat causes breathing difficulties, seek urgent medical attention (Needham et al., 1991; Diaz, 2009). Tick paralysis usually presents as ataxia followed by an ascending paralysis starting in the feet and legs, and may lead to respiratory failure and death. Fever is rare, and constitutional symptoms, which only sometimes precede the paralysis, are limited to malaise and listlessness. Sensory abnormalities, primarily numbness and tingling in the face and limbs, are frequently reported by patients. The disease can present as acute ataxia without muscle weakness. If the tick is not found and removed from the patient, the paralysis can ascend to the trunk and affect respiratory muscles, which can be life-threatening. Cranial nerve involvement has also been described, although it is not common and almost never occurs in the absence of other neurological signs. Patients may report minor sensory symptoms, but constitutional signs are usually absent. Deep tendon reflexes are usually decreased or absent, and ophthalmoplegia and bulbar palsy can occur. Electromyographic (EMG) studies usually show a variable reduction in the amplitude of compound muscle action potentials, but no abnormalities of repetitive nerve stimulation have been studied. These appear to result from a failure of acetylcholine release at the motor nerve terminal level. There may be subtle abnormalities of motor nerve conduction velocity and sensory action potentials (Bolgiano and Sexton, 2009; Traub and Cummins, 2012).

4. Ticks Species Causing Paralysis

In addition to tick-borne diseases, a toxin can be transmitted through the saliva of a tick bite that causes progressive paralysis, a condition known as tick paralysis. Tick paralysis is the only tick-borne condition not caused by a bacterium or other infectious organism. It is characterized by an acute ascending flaccid motor paralysis caused by the injection of a toxin by certain ticks while feeding. Examples are paralysis caused by the feeding of Dermacentor andersoni, sweating sickness caused by Hyalomma truncatum, tick paralysis caused by Ixodes holocylus, and tick toxicosis caused by Rhipicephalus species. Tick paralysis is most common in late winter and spring when the adult ticks are active, but it can occur at any time if the weather is warm and humid. Paralysis in cattle caused by Ixodes holocyclus and Dermacentor andersoni has also been reported by Lysyk et al., (2005).

4.1. American Dog Tick Dermacentor variabilis (Say)

American dog tick Dermacentor variabilis (Say) tick paralysis can occur due to the feeding of D. variabilis. In this case, illness is caused by a neurotoxin produced in the tick's salivary glands. After prolonged attachment, the engorged tick transmits the toxin the tick will attach to the back of the host's neck, or at the base of the skull, and feed for at least five to six days. Paralytic symptoms then become visible through unsteadiness and loss of reflex actions. If the tick is not removed, respiratory failures can be fatal. Such paralysis is not limited to animals, as it can
happen to children as well. The 8-legged adult male and female *D. variabilis* ticks are typically brown to reddish-brown in color with gray or silver markings on their scutum (dorsal shield). The female will vary in size depending on whether or not it has blood fed. Unfed females are typically 5 mm long and are slightly larger than males, which are about 3.6 mm long. Females can be distinguished by a short or small dorsal scutum, right behind the mouthparts while the male scutum covers the majority of its dorsal surface. Blood-fed (engorged) females can enlarge up to 15 mm long and 10 mm wide. The mouthparts and their base, also known as the capitulum, are visible when viewing from above, with the second segment of the palps about as long as it is wide. The anal and genital openings occur on the underside of ticks. Only adults possess genital openings. Posterior to the anus, there is a groove and the spiracular plate is directly behind the fourth coxae (leg attachment segment). There are two stages of immature ticks, 6-legged larvae and 8-legged nymphs. Larvae are 0.62 mm long and yellow before blood-feeding and gray to black when engorged. Nymphs are about 0.9 mm long, and a pale, yellow-like brown before blood-feeding become slate gray when engorged (Smith and Whitman 1992). Both stages of immature tick will have red markings near their eyes and will lack white coloration on the scutum (shield). Nymphs can be distinguished from adults by the lack of a genital opening. *Dermacentor variabilis* develops from the egg stage, to the 6-legged larva, to the 8-legged nymph, and finally to the adult. The cycle requires a blood meal before progression from larva to nymph, from nymph to adult and by the adult for egg production. This cycle also requires three different hosts and requires at least 54 days to complete, but can take up to two years depending on the host availability, host location and the temperature. After 5 to 14 days of blood feeding, a fully engorged female *D. variabilis* drops from the host. It digests the blood meal and develops its egg clutch over the next 4 to 10 days. It then lays anywhere from 4,000 to 6,500 eggs on the ground and about 26 to 40 days later, depending on the temperature, the eggs hatch into larvae. After hatching, larvae remain on the ground or climb to growing vegetation where they wait for small mammals, such as mice, to serve as hosts for their first blood meal. This host location behavior is called questing. Under favorable conditions, larvae can survive up to 11 months without feeding. After contacting and attaching to a host, larvae require from 2 to 14 days to complete blood feeding. After feeding, larvae detach from their host and fall to the ground where they digest their blood meal and molt into the nymphal stage. This process can take as little as a week, although this period is often prolonged. Nymphs can survive six months without a blood meal. After successfully questing for their second host, which is normally a slightly larger mammal (such as a raccoon or opossum), the nymphs will blood feed over a 3 to 10 days period. After engorging, they fall off the host, digest their blood meal and molt into an adult. This process can take anywhere from three weeks to several months (Mcnemee et al., 2003; Burke et al., 2005).

Adults can survive two years without feeding, but readily feed on dogs or other larger animals when available. Questing adult ticks climb onto a grass blade or other low vegetation, cling to it with their third pair of legs, and wave its legs as a potential host approaches. As the hosts brush the vegetation, the ticks grab onto the passing animal. Mating occurs on the host and the female engorges within 6 to 13 days after which it drops from the host to lay its eggs and then dies, thus completing the cycle (Burg, 2001). Adult American dog ticks overwinter in the soil and are most active from around mid-April to early September. Larvae are active from about March through July and nymphs are usually found from June to early September. The American dog tick is the primary vector for the pathogen causing Rocky Mountain spotted fever the causative agent is primarily vectored by *D. variabilis* to dogs and humans following its acquisition from rodents.
The tick toxin's pathogenic mechanism is not fully understood. Investigators have reported that the toxin inhibits acetylcholine release at the neuromuscular synapse. It is not clear whether the same mechanism is at work in paralysis caused by *Ixodes* species and that caused by *Dermacentor* species (Goddard, 2002).

### 4.2. Paralysis by Tick *Ixodes holocyclus*

The most medically important tick, the paralysis tick, *Ixodes holocyclus*, can be roughly found in a variety of habitats but are especially common in wet forests and temperate rainforests or where much of the human population resides. They have very few predators, and are more likely to succumb to desiccation from high temperatures and low humidity. From the enormous numbers of eggs (2,500-3,000) deposited in the moist leaf litter by the female before it dies, only a fraction of the eggs can survive and eventually grow to become adults. The six-legged larvae hatch after the eggs have incubated for 40-60 days. To molt, the larval tick must obtain a blood meal. In searching for a host, they display a behavior referred to as questing; whereby the tick climbs to the top of nearest vegetation and waves its forelegs to and fro slowly, hopefully contacting a prospective passing host. There is usually a native animal such as a bandicoot, which is the main host, but also possums, kangaroos, and humans. This questing behaviour is undertaken each time a host is required for blood. Ticks usually do not climb more than around 50 cm in the vegetation and there is no evidence to suggest that they fall out of trees. Once a suitable host is found, the larvae will blood feed for 4-6 days, drop from the host and molt to the eight-legged nymphal stage. Nymphs require a further blood meal for 4-8 days before molting to the adult stage. Both female and male ticks quest for a host, but for different reasons; the female for a blood meal, the males to search the host for female ticks in order to mate and sometimes feed from them. Males may actually parasitize the female ticks by piercing their cuticle with their mouthparts to feed on her haemolymph (the tick's blood) and up to 3-4 males have been found feeding on one female tick. Male ticks rarely blood feed on a host. The adults female paralysis tick will feed for up to around 10 days, drop off the host and lay eggs over several weeks. The entire life cycle of the paralysis tick, involving 4 stages and 3 hosts, will take around a year to complete. Each life stage can be present throughout the year, although for the paralysis tick, adults are more abundant in the spring and the early summer months, larvae in mid to late-summer, and nymphs during winter (Wright et al., 1983; Newot et al., 2015).

### 5. Mechanism of Pathogenesis

Tick paralysis is believed to be due to toxins found in the tick’s saliva that enter the bloodstream while the tick is feeding. The two ticks most commonly associated with tick paralysis are the Rocky Mountain wood tick (*Dermacentor andersoni*) and the American dog tick (*Dermacentor variabilis*); however, 43 tick species have been implicated in human disease around the world. Most cases of tick paralysis occur from April to June, when adult Dermacentor ticks emerge from hibernation and actively seek hosts. In few areas, tick paralysis is caused by the tick *Ixodes holocyclus* and fatal cases have been reported. Although several attempts have been made to isolate and identify the neurotoxin since the first isolation, the exact structure of the toxin has still not been published. The 40-80 kDa protein fractions contain the toxin (Stone et al., 1989). Although tick paralysis is of concern in domestic animals and livestock as well, human cases are rare and usually occur in children under the age of ten years. Tick paralysis occurs when an
engorged and gravid (egg-laden) female tick produces a neurotoxin in its salivary glands and transmits it to its host during feeding. Experiments have indicated that the greatest amount of toxin is produced between the fifth and seventh day of attachment (often initiating or increasing the severity of symptoms), although the timing may vary depending on the species of tick (Masina and Broady, 1999; Dworkin et al., 1999).

6. Diagnosis of Tick Paralysis

Diagnosis is based on symptoms and upon finding an embedded tick, usually on the scalp. In the absence of a tick, the differential diagnosis includes Guillain-Barre syndrome (a disorder in which the body's immune system attacks part of the peripheral nervous system and the first symptoms of this disorder include varying degrees of weakness or tingling sensations in the legs). Tick paralysis is often confused with Guillain-Barré syndrome, which is clinically similar and much more common than tick paralysis. Unfortunately, electrophysiological tests are not useful in distinguishing between the two. In addition, there are no specific blood tests for tick paralysis, and conventional blood and spinal fluid studies are almost always normal. Thus, correct diagnosis is contingent upon physician awareness. Any case involving sudden-onset ataxia and ascending paralysis, especially in a patient who lives in a tick-endemic area and who fits the demographic profile described above, should be considered suspicious for tick paralysis. Such patients should be searched immediately for ticks, particularly in body areas where the tick might not be immediately apparent, such as the scalp, hairline, ear canals or pubic region (Piesman and Gage, 1996; Thorner et al., 1998).

7. Management of Tick and Paralysis

The American dog tick occurs primarily in wooded, shrubby and long-grass areas. However, it is possible for residential areas to support populations of this tick. Shrubs, weeds, tall grass, clutter and debris on the land attract the rodents that are hosts for immature ticks. By maintaining grass short, removing possible rodent harborage, and sealing cracks and crevices in and around the residence, anyone can directly reduce or prevent local tick populations. Keeping grass and weeds cut short decreases humidity, which helps to kill ticks or makes an area undesirable for ticks and rodents. Additionally, it makes difficult for ticks to climb on the vegetation and wait for its host. If pesticides are applied, cutting the vegetation short increases effectiveness and allows for better coverage. Removing rodent harborage areas may reduce an infestation. Because dogs can easily pick up ticks while walking on infested grass or roaming through wooded areas, it is necessary to treat the pet properly. There are many products that can be applied to prevent or treat a tick infestation on an animal including topical treatments and sprays. Regularly grooming, washing bedding and examining the dog are strongly recommended to prevent tick infestations (Greenstein, 2002).

In locations where peoples live and they contact ticks in their backyard, then strategies can be undertaken to reduce the tick population and thereby minimize exposure. The tick causing paralysis is very susceptible to dry conditions and so decreasing soil moisture can lessen their impact. This can be achieved through the reduction of foliage cover, which increases sunlight penetration to the ground, reducing the shrub layer, reducing mulching and watering, and ensuring that the lawn is kept mown low. Bandicoots, the main host of the paralysis tick, can be kept out of the backyard through the use of animal exclusion fencing. This needs to go below the
ground surface by 0.5m so that the animals cannot dig underneath. If ticks continue to be a problem, then insecticide control is an option. It is normal for a tick bite to remain slightly itchy for several weeks, however if other symptoms develop, then a consultant should be consulted immediately (Demma et al., 2005; Goddard and Layton, 2006).

7.1. Removal of Ticks from Hosts

Ticks should not be removed by handpicking because infected tick secretions can be transferred from a person's hands to eyes, mucous membranes, mouth, etc. Therefore, forceps should be used when removing a tick (Smith and Whitman 1992). To properly remove a tick, grasp the mouthparts near the attachment site firmly with tweezers. Once the mouthparts are held, the tick should be pulled straight back slowly to ensure that the entire mouthparts are removed from the body. It is important that the tick is removed slowly because the mouthparts are covered in sharp, backward directed barbs which assist the tick in holding onto its host. Sometimes, by removing the tick, a piece of the host's skin may break off, which should not be a great concern, but bears watching for infection or later reaction. To treat the wound, it is important to wash the area with soap and water followed by an antiseptic. Once the tick is removed, the recommendation is to save it in alcohol, with the date the tick is removed, in case when it is needed for identification or pathogen testing. If no symptoms occur within a month of removal, the tick may be discarded (Crawford and Mitchell, 2009).

7.2. Prevention of Tick Paralysis

As a rule, if children are discovered to have ticks, it is a good idea for parents to write the information down and keep it for several months. Many tick-borne diseases do not show symptoms immediately, and the incident may be forgotten by the time a child becomes sick with a tick-borne disease. Further, no human vaccine is currently available for any tick-borne disease, except for tick-borne encephalitis. Individuals should therefore take precautions when entering tick-infested areas, particularly in the spring and summer months. Preventive measures include avoiding trails that are overgrown with bushy vegetation, wearing light-colored clothes that allow anyone to see the ticks more easily, and wearing long pants and closed-toe shoes. Tick repellents containing DEET (N, N-diethyl-m-toluamide) are only marginally effective and can be applied to skin or clothing. Rarely, severe reactions can occur in some people who use DEET-containing products. Young children may be especially vulnerable to these adverse effects. Permethrin, which can only be applied to clothing, is much more effective in preventing tick bites. Permethrin is not a repellent but rather an insecticide; it causes ticks to curl up and fall off the protected clothing (Vedanarayanan et al., 2002; 2004).

7.3. Treatment of Tick Paralysis

Unlike lyme disease, ehrlichiosis and babesiosis, which are caused by the systemic proliferation and expansion of parasites in their hosts long after the offending tick is gone, tick paralysis is chemically induced by the tick and therefore usually only continues in its presence. However, in some cases, profound paralysis can develop and even become fatal before anyone becomes aware of a tick's presence. Once the tick is removed, patients usually recover quickly and symptoms usually diminish rapidly. Improvement is commonly noted within hours and further
treatment is not required. Removal of the embedded tick usually results in resolution of symptoms within several hours to days. If the tick is not removed, the toxin can be fatal, with reported mortality rates of 10-12 percent, usually due to respiratory paralysis. The trick is best removed by grasping the tick as close to the skin as possible and pulling in a firm steady manner (Sonenshine, 1991). Unlike the other species of ticks, the toxin of *Ixodes holocyclus* (Australian paralysis tick) may not resolve itself and can be fatal if medical assistance is not immediately sought after pulling the tick off of the body. Contrary to popular belief, if the head detaches from the body while being pulled off, leaving the head will not inject more venom. The head may cause a skin irritation but it will not inject any more venom. Once the tick is removed, place it in a clear bag preferably ziplock, so that the expert can identify it (Needham, 1985; Edlow. and McGillicuddy, 2008; Diaz, 2010).

8. Conclusions

Ticks transmit a number of infections to humans and other animals, however, the toxins of various ticks can also cause a disease known as tick paralysis, which can be confused with both infectious and noninfectious conditions. Tick paralysis is the only tick-borne disease that is not caused by an infectious organism and the illness is caused by a neurotoxin produced in the tick's salivary gland. After prolonged attachment, the engorged tick transmits the toxin to its host. Human females are affected more often than males, possibly because ticks are more likely to remain undetected following attachment to individuals with long hair and generally the tick may be attached to the victim’s head or neck. Younger children are more susceptible to tick bite paralysis and peoples living in tick prone areas must inspect their children from time to time taking care to check areas hidden under the hair. However, if diagnosed promptly, this illness can be cured with the combination of tick removal and supportive care. Conducting a thorough search for an embedded tick is essential in a patient with an acute ascending paralysis with preserved sensorium, particularly when there is a history consistent with potential tick exposure. The treatment of tick paralysis is simple, remove the tick from the body of host and clinical improvement in health may result within few hours. The proper way to remove a tick is to grab it with blunt forceps as close to the skin as possible and pull it straight out with steady pressure. Do not apply a hot nail or blown-out match to the critter’s backside, do not use tweezers or sharp forceps and avoid using a twisting or corkscrew motion in removing the tick. Do not crush or squeeze the tick's body, as that can cause the tick to release more of the infectious organism or toxin, and never handle the tick barehanded because there have been documented cases of disease transmission in peoples who did that. In the last some years, very little new information on the medical and veterinary significance of ticks has been published in other parts of the world. For sustainable ticks control; routine monitoring of tick levels on pets, identifying of hotspots, adoption of prevention practices, multiple and properly timed yard treatments, and making necessary adjustments to change in knowledge and attitudes of society to maintain low-levels of tick infestation, are vital and necessary to knock down tick’s population for continued control. Given the increasing interest to tick-borne diseases and the recognition to their growing importance, it is time that more work should be done in this area in South-east Asia.

References


