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The Brown Dog Tick and Epidemic Rocky Mountain spotted fever in Arizona and northwestern Mexico

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Introduction

The brown dog tick *Rhipicephalus sanguineus*, has a worldwide distribution and is found throughout the United States (US) and Mexico. This tick is driving epidemics of Rocky Mountain spotted fever (RMSF) in Arizona and northwest Mexico. As the name suggests, the tick mainly takes blood meals from dogs, but it will also feed on humans and other mammals, and can carry serious disease causing pathogens. In the early 2000's it was found to transmit *Rickettsia rickettsii*, (a gram-negative, intracellular, coccobacillus bacterium) that causes RMSF in Arizona. This was the first time this tick species has been associated with the disease in the US (Demma et al. 2005). Similar outbreaks occurred at the same time in Sonora and more recently in Baja California (Alvarez-Hernandez et al. 2017).

An unusual feature of the brown dog tick is its tendency to live around or inside homes, where it can be found crawling on walls and furniture. Outdoors, it may shelter in cracks or crevices of buildings or backyard clutter. Unlike most ticks in North America, when dogs bring ticks from the natural habitats into yards and even inside homes, the ticks may survive and propagate in this environment. Ticks in domestic settings may feed on humans and other mammals, increasing the risk of R. *rickettsii* transmission. The key to controlling this disease lies in treating tick infestations on dogs and around homes.

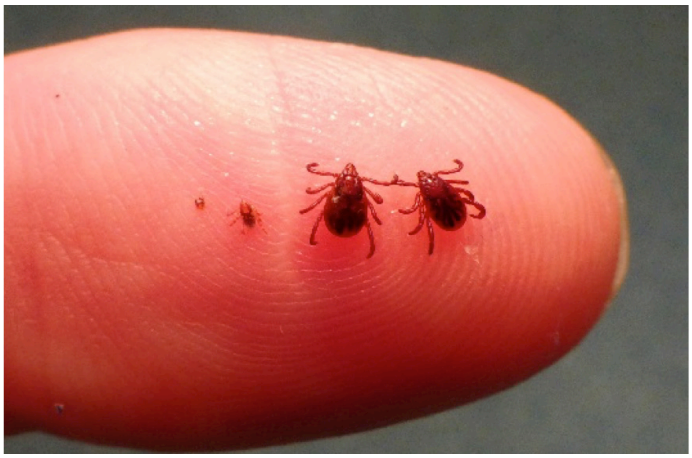
Brown Dog Tick Distribution in Arizona and northern Mexico

While the brown dog tick is most common in warmer regions of the world, it can survive cold winters indoors, especially in kennels, and is present in all states of the continental US. Within Arizona, this species has been documented in Coconino, Gila, Maricopa, Navajo, Pima, Santa Cruz and Yavapai, Yuma counties and is likely present throughout the state. The brown dog tick is also found throughout Mexico (Herrera-Hernández et al. 2016). Its presence has been documented in the states of Coahuila, Durango, Guanajuato, Morelos, Nuevo Leon, San Luis Potosi, Sinaloa, Sonora, Baja California, Veracruz and Yucatan, and it was the most common tick species found in a recent national survey (Sosa-Gutierrez et al. 2016). In contrast to populations in the US, the brown dog tick has been known to vector *R. rickettsii* in Mexico since the 1940s (Bustamante and Varela 1943). Serious RMSF outbreaks have re-emerged in the early 21st century, particularly in the northwest of Mexico (Alvarez-Hernandez et al. 2017).

While the brown dog tick is referred to as a single species, *Rhipicephalus sanguineus* is really a complex of related species or subspecies (Dantas-Torres 2008). Taxonomists do not agree on how to separate the species, but generally recognize two main lineages – a tropical group and a temperate group (Dantas-Torres et al. 2013). A recent study found both the tropical and temperate groups present in the Arizona brown dog tick populations (René-Martellet et al. 2017).

Identification & Life Cycle

The brown dog tick has four life stages – egg, larva, nymph and adult. Each stage is separated by a molting process in which the tick sheds its exoskeleton. After hatching from the egg, the tick must find a new host animal to feed on at each successive life stage. In the larva or 'seed tick' stage, the tick is light colored, has only six legs and is about the size of a pinhead, making it easy to overlook. In the nymph and adult stages, the tick has 8 legs and is reddish brown in color. Unlike some other common tick species that feed on dogs, it has no distinct light or dark markings on its back. The body is



Larva, nymph and adults. Photo by Dr. Michael Levin, CDC

elongated with a small head. Before feeding, adult females are between 3 to 6 mm in length while males are slightly smaller (Lord 2011). After blood-feeding, adult females can stretch to 12 mm in length and change to gray or olive-colored (Dantas-Torres 2008).

In warm weather with access to dog hosts, the entire lifecycle of the tick can take as little as two months. In optimal tropical conditions, the brown dog tick can produce as many as four generations in one year (Dantas-Torres 2010).

Male (above) and Female (below) adult brown dog tick (Rhipicephalus sanguineus) – Photos by Centers for Disease Control (CDC)

Biology and Ecology

a. Hosts.

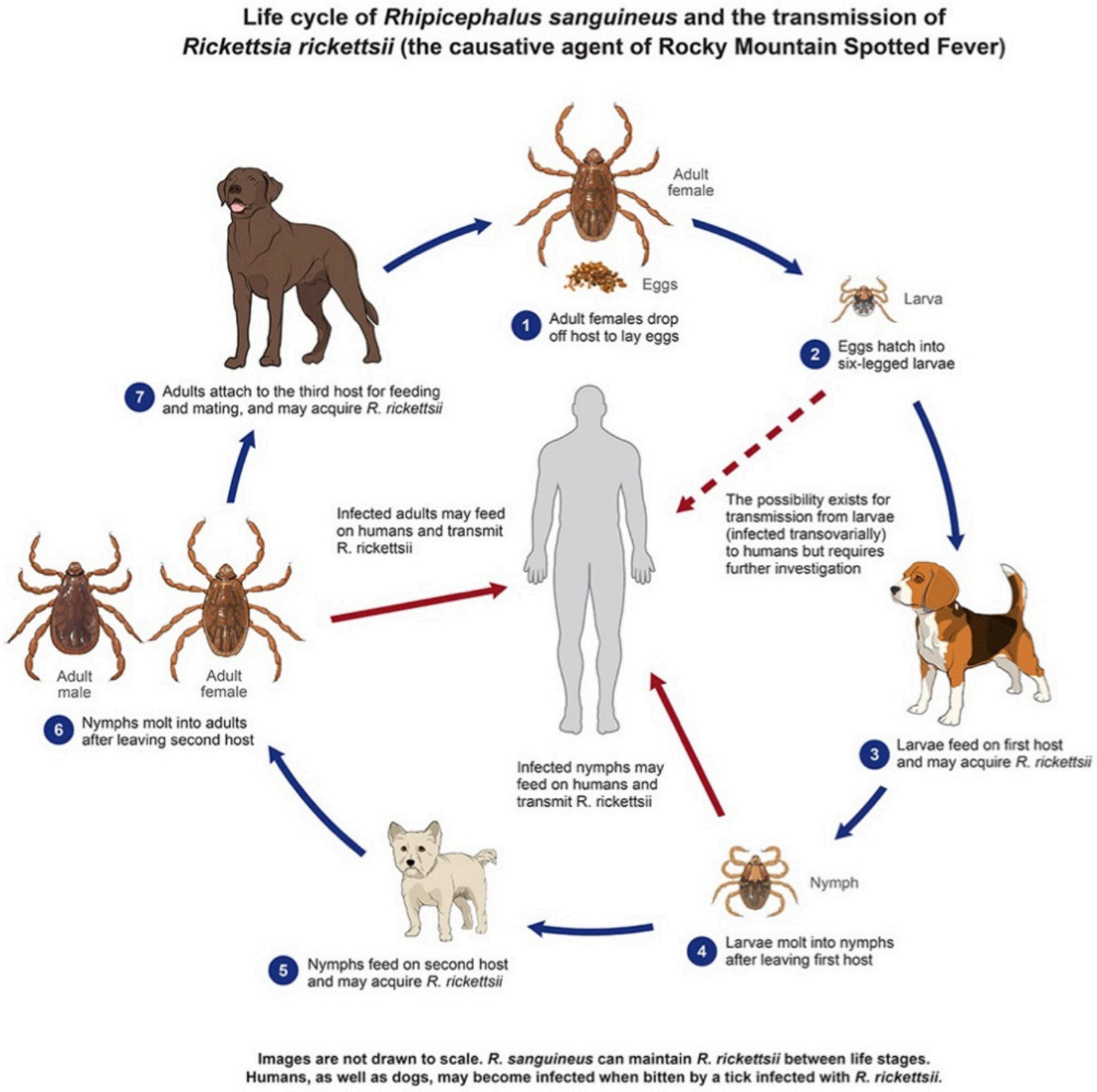
Like all ticks, the brown dog tick feeds exclusively on blood. They must take a blood meal at each life stage, usually on a new host animal. All life stages of the brown dog tick show a strong preference to feed on dogs, but will occasionally feed on other vertebrate animals including humans, cats, rodents and birds. It may move onto non-dog hosts such as humans when there are dramatic increases in tick populations (Dantes-Torres 2008). A study in France found this tick is more likely to bite humans at higher temperatures (32 and 40˚C) than at a lower temperature (25˚C) (Parola et al. 2008).

When searching for a host, the brown dog tick has multiple strategies that are important to consider for managing this tick and preventing RMSF outbreaks in humans (Dantas-Torres 2010). The tick can actively seek out hosts in the environment, using cues like CO2, heat and vibrations that stimulate the tick to run towards the host. Another behavior is questing, in which the tick waits on the tips of vegetation waving its legs until a host animal brushes against the vegetation, but this behavior has not been observed in brown dog ticks in Arizona. Finally, the tick may spend its life in the host's living area. As dogs usually live with humans, the host's living area can be inside or around a home, leading to significant indoor infestations (Nicholson et al. 2006). While the time spent on the host is important for feeding, the brown dog tick spends most of its life (95%) off the host and in the environment.

b. Blood-feeding.

Once the tick has found its dog host, it moves to a preferred feeding spot, and uses its mouthparts to pierce the skin. While it prefers the ears and neck, it can attach anywhere on the dog. It inserts a specialized structure called the hypostome that serves as an anchor to keep the tick attached. Barbs on the hypostome make it hard to pull the tick out. The hypostome of the brown dog tick is shorter than many other tick species, but removing an attached tick is still difficult (Dantas-Torres 2010). The tick also secretes a cement-like substance that forms a feeding cone around the mouthparts. While feeding, the tick alternates between periods of sucking blood and injecting saliva into the wound (Parola and Raoult 2001). The repeated movement of tick saliva into the wound plays an important role in transmitting *R. rickettsii* and other pathogens (Dantas-Torres 2008). Co-feeding transmission of pathogens happen when a pathogen transfers between an infected and uninfected tick during close proximity feeding on a host. Brown dog ticks often group together when actively feeding on a host, and co-feeding transfer of *Rickettsia* species from infected to uninfected ticks has been documented (Zemtsova et al. 2010).

Once feeding is complete, the tick drops off the host and moves to a secluded location in the environment to finish digestion. While feeding may take two days to several weeks, pathogen transmission can occur quickly. The length of the blood-feeding period differs between the different life stages. Larvae only feed for about two days before dropping off the host, while adult females can stay feeding on the host for



Credit: CDC

more than a week. Adult ticks may feed on more than one host (Dantas-Torres 2010). Larvae tend to drop off during the day, while nymphs and adult females tend to drop off at night when the host dog is usually sleeping, thus increasing the chances of a tick infestation in or near the home (Paz et al. 2008).

c. Reproduction.

Brown dog ticks only mate on the host while the female is feeding. In fact, the adult female will not become fully engorged until mated (Dantas-Torres 2010). After mating, males may seek another female, possibly on another host. The female will also finish blood-feeding and drop off the host, waiting for a period of days to weeks for the eggs to mature. Then she will lay 1,500 to 4,000 eggs in protected locations, such as cracks or crevices in the wall of a building (Koch 1982).

Medical Significance in Arizona & Sonora

a. Diseases.

The brown dog tick is one of the most important vectors of diseases in dogs worldwide. In the US and Mexico, this tick

carries canine ehrlichiosis and canine babesiosis. Both diseases can cause fever and other serious symptoms in dogs. It has also been found to vector canine anaplasmosis in Sonora, Mexico (Robles Graham 2012). It is not known to vector Lyme disease (Dantas-Torres 2008). While the brown dog tick is associated with transmitting RMSF in the southwestern US and Mexico, most cases of RMSF in North America are transmitted by other tick species.

b. Recent history of RMSF in Arizona and Sonora.

Between 2003 and 2017, the brown dog tick caused more than 380 human cases of RMSF and 23 deaths in Native American communities in Arizona (Drexler et al. 2014; ADHS published data). All reported cases have occurred in six reservations, dispersed throughout the state. Overall, cases of RMSF have declined significantly since 2014, but new cases are reported annually from impacted areas. The majority of cases involved children who acquired the tick bites in or around the home.

During that same period in neighboring Sonora, 1,394 human cases with 247 deaths were reported (Straily et al. 2016; Alvarez-Hernandez et al. 2017). Cases were most common in low-income, rural communities with limited access to health care, particularly among indigenous migrant agricultural workers. Children under ten years old appear especially vulnerable to serious health complication, and fatality rates of 40% have been observed in indigenous patients at the Sonora Children's Hospital (Alvarez et al. 2014).

An RMSF outbreak occurred in 2009-10 in Mexicali, Baja California. Between the first outbreak and 2016, 967 cases were reported in the area with 132 deaths (Alvarez-Hernandez et al. 2017).

c. RMSF symptoms.

Symptoms of RMSF usually occur 3—12 days after a bite from an infected tick. Unfortunately, about 40% of RMSF patients in the US did not notice or remember the tick bite, which can lead to misdiagnosis (Masters et al. 2003). Symptoms are very nonspecific and can include fever, headache, malaise, muscle pain and nausea/vomiting/diarrhea. The name "spotted fever" refers to a maculopapular rash of typically small, flat, pink spots that develops on the wrists and ankles spreading centrally. The rash does not itch. As illness progresses, the spotted rash becomes more distinct and can be seen on the palms of the hands and the soles of the feet. The onset of rash can be delayed until 5 days after fever, although some patients (~30-60%) may never develop a rash (CDC 2017). Rash is a sign of damage to the blood vessels in the skin, and as damage progresses these areas can become necrotic and gangrenous. Amputation may be required in some cases. RMSF can be hard to diagnose, as the symptoms are general to many illnesses. Delay in diagnosis, however, can have serious consequences. RMSF can have severe clinical outcomes and even be fatal within eight days if not treated properly (Traeger et al. 2015).

Diagnosis is even more complicated in Sonora and other regions in Mexico due to the similarity of symptoms of RMSF and other widespread febrile illnesses, particularly dengue. Because RMSF is not a first line diagnosis, doctors may delay treatment, contributing to a fatality rate of 30% among infected children (Alvarez and Contreras Soto 2013; Masters et al. 2003).

d. RMSF Treatment.

The recommended treatment is doxycycline, which should be prescribed as soon as RMSF is suspected. The standard treatment is 5 to 7 days with the following dosage:

- Adults = 100mg twice a day
- Children (under 100 lb) = 1 mg per lb body weight twice a day.

Treatment should be continued for at least 72 hours after fever subsides AND until the patient improves (CDC 2017). Doxycycline is approved for use in adults and children of all ages for the treatment of RMSF; recent research shows no evidence of tooth staining in children when used in short courses (Todd et al. 2015).

Brown Dog Tick Management and RMSF Prevention

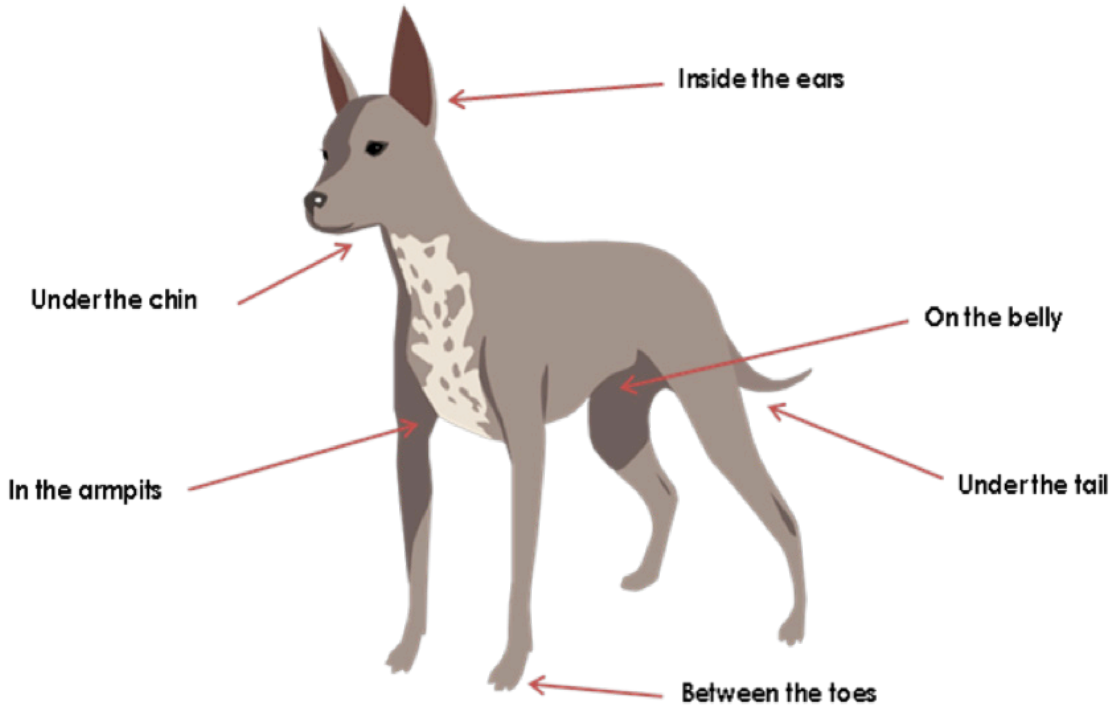
Main risk factor. As dogs are the preferred hosts, the abundance and condition of dogs influences brown dog tick populations as well as the risk of human RMSF. While the dogs cannot transmit *R. rickettsii* directly to humans or other dogs, infected dogs can bring ticks into homes where the ticks may drop off and later feed on a human or another dog, continuing the *R. rickettsii* transmission cycle. Once introduced into the peridomestic environment, this tick can complete multiple generations entirely indoors.

Of particular importance are free-roaming dogs, meaning dogs that may be associated with a particular home but move freely between yards, potentially spreading ticks. Once infected, a dog may become a reservoir of *R. rickettsii*, meaning other brown dog ticks can acquire the bacteria when they feed on the infected dog. RMSF causes serious illness and even death in dogs as well as humans. Large numbers of immunologically naive (uninfected) puppies create opportunity for easy tick predation and viable hosts for continued *R. rickettsii* transmission. Tick control on dogs needs to be coupled with tick control in the environment to limit ticks to ensure that brown dog ticks left in the environment do not look to humans for alternative blood meals.

a. Surveillance

Canine Tick Load Assessment. The main form of surveillance for the brown dog tick involves assessing the tick burden on dogs. Dogs are examined and the burden of ticks are roughly categorized. Ideally, personnel should wear gloves and use forceps or tweezers. There is no need to remove ticks if a tick collar is being fitted to the dog at the time of assessment. While adult ticks are most commonly found around the ears, a tick assessment should systematically examine all the areas in the figure on the next page:

While the ideal assessment would involve all dogs in a community, if the dog population is too large, a sample of dogs may be examined. The sample should represent the dog population as whole, and not be biased by excluding some dogs (e.g. indoor or outdoor dogs, dogs without collars).



(credit: ADHS Handbook)

Testing samples for R. rickettsii To evaluate for presence of *R. rickettsii*, ticks may be removed and killed in a freezer or by placing in rubbing alcohol. Carefully place the tick(s) into a secure container, screw cap vial or plastic bag; place the primary container (or bag) inside a sturdy plastic bag. Place ticks from collection sites into separate containers, marking each container with appropriate identifying information so that each sample can be matched to its corresponding location. Ticks can then be sent to specialized laboratories for testing by polymerase chain reaction (PCR). Tick testing can provide a useful tool for establishing the presence of *R. rickettsii* in an area, but tick testing alone cannot be used to estimate human disease risk.

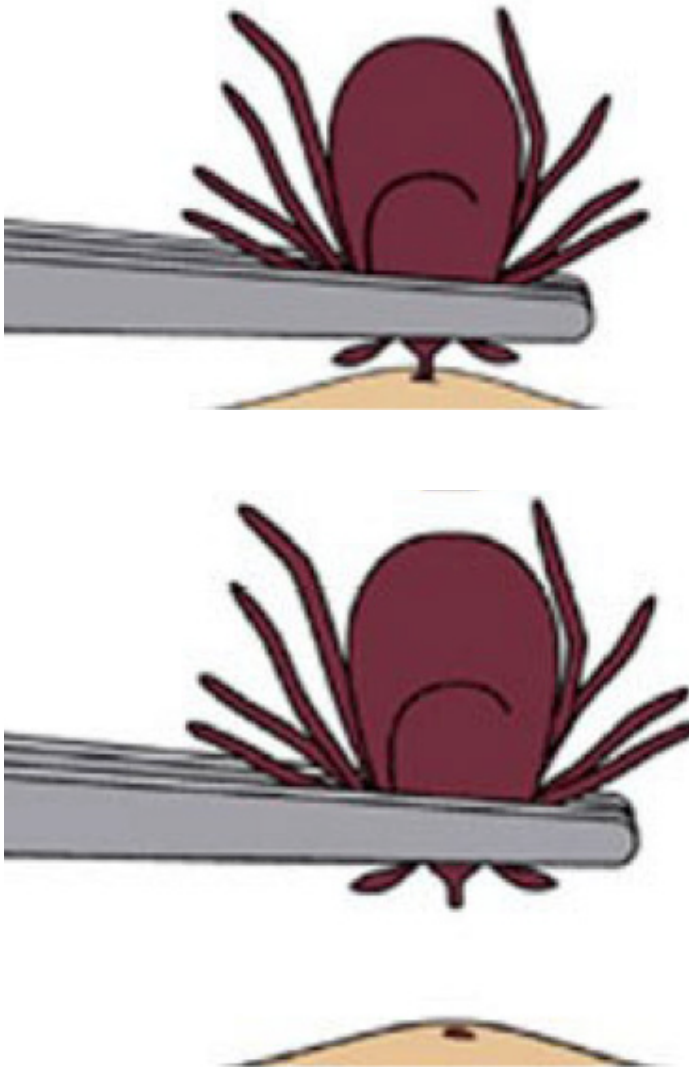
Environmental Assessment. TThe brown dog tick population may also be measured by collecting ticks from the environment. One method is trapping using a CO2-baited tick trap. Traps consist simply of a collecting cloth or tarp secured to the ground and a plastic container with holes containing dry ice. The CO2 escaping from the container attracts the host-seeking ticks to the cloth where they can then be collected.

Traps should be placed outdoors around homes in shady areas used by dogs. To accurately estimate tick numbers, at least three traps should be deployed per house. Traps should remain in place for 3 to 4 hours, at which point the collecting cloth is folded up with the ticks present and sealed in a bag for identification and possible disease testing (Drexler et al. 2014). While this sampling method has been a good assessment tool in Arizona, environmental conditions such as temperature and wind can influence results. Other sampling methods such as flagging do not generally work well for this tick species.

For more information on tick trapping, see the Appendix 4: Tick Trapping Guide of the Arizona Department of Health Services RMSF Handbook. http://www.azdhs.gov/documents/preparedness/epidemiology-disease-control/rocky-mountain-spotted-fever/rmsf-handbook.pdf

b. Human tick checks and removal.

Infected ticks can start to transmit pathogens to humans within two hours. It is important to remove attached ticks as soon as possible to limit the chance of pathogen transmission. Ticks are often found under the arms, in and around the ears, inside the belly button, behind the knees, between the legs, around the waist, and especially in the hair. Children should be taught to check themselves for ticks and may need help checking on the scalp under hair. If found, any tick should be removed immediately with fine tweezers, if available. If ticks are removed using bare hands, avoid squashing the ticks between fingers and wash hands thoroughly with soap afterwards. The tick should be grasped close to the skin and gently pulled off. Try to avoid breaking the tick. Folklore techniques for removing a tick by smothering it with petroleum jelly or holding a hot match to it DO NOT work and can actually increase the risk of disease transmission (Allen 2008). The tick may be preserved in a small container with rubbing alcohol in case there are health concerns later. After the tick is removed, the wound should be washed with soap and water. The tweezers and hands of the person removing the tick should also be thoroughly cleaned.



Credit: CDC

c. Tick control on dogs.

As dogs are the preferred host for the brown dog tick as well as the primary means of bringing these vectors into the home environment, direct treatment of dogs to prevent tick infestations is an effective way to prevent RMSF. In the Arizona/Sonora region, year round tick control is advised. The treatment options include tick collars, topical or spot-on treatments, and oral products. While all these treatments can help decrease tick infestations, it is still recommended to regularly check pets for ticks. Many of these products are not safe to use on young puppies, so be sure to check the label before using. Products containing permethrin (e.g. Activyl Plus, Vectra 3D) are toxic to cats. When applying collars or topical treatments, dispose of the wrapper or product container safely and wash hands thoroughly with soap and water. If you are applying products to more than one animal, it is strongly advised that you wear gloves (Weirda and Gouge, 2017).

Collars. Tick collars are relatively long-term products that either kill or repel ticks. Duration of effectiveness varies between 3 and 8 months, depending on the product. Table 1 provides a summary of currently available products and recent US prices. Do NOT use older tick collars that contain the insecticide propoxur, as they pose a significant health risk to children who come in contact with the collar (Wierda and Gouge 2017). Because the collars are worn constantly, the products used are designed to minimize pesticide risks for humans and pets. It is essential, however, to practice safe handling techniques to avoid unnecessary exposure.

Photo Credit: Dawn Gouge

Topical treatments. TThese products may be highly effective but tend to last only one month. The treatment is generally applied to the back of the neck or between the shoulder blades to avoid the dog licking the treated area. After treatment, make sure all family members avoid touching the dog's head or neck for about 24 hours.

Oral treatments. These products are taken as pills or chewable tablets. This reduces the pesticide exposure risk to humans. The treatment typically lasts one to three months. The disadvantage is that treatment is usually more expensive than collars and may not be suitable for dogs with certain health problems.

Safe handling techniques. Tick control products typically come with the following safety instructions that should be followed to avoid dangerous pesticide/medication exposure:

- Keep out of reach of children.
- Avoid contact with eyes, skin and clothing.
- Wash hands thoroughly with soap and cold water after applying the product (or fitting the collar).

Additional safety considerations for applying collars or topical tick treatments include wearing protective clothing such as long sleeves and pant and gloves to minimize skin exposure. Most pesticide exposure to skin occurs through the hands. Wearing gloves reduces that exposure by 99% (Weirda and Gouge 2017).

d. Tick control around homes.

As the brown dog tick favors protected harborage sites; areas under and near the home should be free from clutter. Items such as furniture, firewood, tall grasses or brush, and leaf litter should be removed or positioned far from the home. If there is a play area for children in the yard, it should be separate from these areas as well. If possible, seal cracks in cement and crevices between stones in the foundation, walls, and other parts of the home.

Acaricides (chemical pesticides that target ticks) can also be applied to control large tick infestations in yards or around homes. Pyrethroid pesticides have been shown to be effective against the brown dog tick, and liquid formulations give higher efficacy. Effective products include liquid bifenthrin (e.g. Bifen IT) or beta-cyfluthrin/imidacloprid (e.g. Bayer Advanced Multi-insect Killer). Bifenthrin granules (e.g Bifen LP, Talstar PL) are safer to apply, but may be less effective unless water is also applied to the treated area (Connecticut Agricultural Experiment Stations 2004). In areas where tick activity is limited seasonally, monthly acaricide applications during the summer are recommended. In warmer climates where brown dog ticks may be active year-round, quarterly applications (every three months) are recommended.

As with all pesticide applications, it is essential to follow safe handling, application, and storage practices as indicated by the EPA. Always read and follow the pesticide label. Pesticides must be used in accordance with federal, state, and local regulations. Applicators should always wear the appropriate personal protective equipment as required by the pesticide label during applications. Pesticides should be stored in a cool, dry, secure place out of reach of children and pets.

Sources for more information on controlling the brown dog tick outside home:

https://www.cdc.gov/ticks/avoid/in_the_yard.html

https://pmu.ifas.ufl.edu/sites/ufpmu/files/TickBMPs.pdf

e. Community RMSF rodeos in AZ and Mexico.

In regions of the US where RMSF is vectored by other tick species, disease prevention is focused on avoiding tick habitat and using repellants (Peisman & Eisen 2008). The brown dog tick, however, lives in and around homes, so another approach is needed to prevent human exposure to this vector. A community-based integrated tick-bite prevention program called the RMSF Rodeo has been developed in Arizona and replicated in Sonora (Drexler et al. 2014; Straily et al. 2016). The RMSF Rodeo approach centers around the dogs in a community. Activities include systematic assessment of tick loads on dogs and placement of tick collars on all dogs in a community. In addition, homes with existing tick infestations are treated with pesticides. Other activities can include solid waste pickups, animal care resources such dog spray and neuter clinics and education campaigns to keep dogs within their yards. This approach has successfully reduced RMSF incidence in several communities in Arizona and Sonora that had experienced RMSF outbreaks.

Summary

- The brown dog tick is the most common tick humans encounter in Arizona and north-west Mexico.
- This tick has been shown to transmit *R. rickettsii*, the bacteria that causes Rocky Mountain spotted fever, a serious illness that can be fatal if left untreated.
- Dogs may bring the ticks from the natural environment into homes or yards. At that point, ticks may lay eggs and establish large populations of ticks around and inside homes.
- This tick prefers to feed on dogs, but will bite humans when brought into the household environment.
- An effective way to prevent RMSF in the Arizona/Sonora region is by protecting dogs from tick infestation. **Use of long-acting tick collars, or other veterinary approved acaricides on all dogs in a community can reduce tick problems.**

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Table 1. Summary of Tick Collars for Dogs (ADHS RMSF Handbook)

Brand Name	Active chemical(s)	Length of effectiveness	Cost per dose	Special Safety Instructions	Other notes
Fly-free zone	Natural products: Citronella/ phenylethyl	"Replace when effectiveness diminishes"	$20	Do not use other products with this collar. Do not use on sick or convalescing dogs.	Untested efficacy, not an EPA registered product, remove for bathing.
Hartz InControl, Hartz Ultraguard	Tetrachlorvinfos	Up to 5 months	$5 - 10	InControl collar for use on dogs at least 12 weeks old; Ultraguard collar for dogs at least 6 weeks old	Organophosphate, possible human carcinogen
Preventics	Amitraz or amitraz-pyriproxyfen	Up to 3 months	$10-20	For use on dogs at least 12 weeks old	Not effective for flea control; use caution when combining with flea treatment. Possible human carcinogen
Scalibor	Deltamethrin	Up to 6 months	$38	For use on dogs at least 12 weeks old.	Some resistance to this product reported in brown dog ticks.
Seresto	Imidacloprid and flumethrin	Up to 8 months	$50 (retail), $25 for public health	For use on dogs at least 7 weeks old.	Water resistant.

Table 2. Summary of Topical and Oral Tick Control Products for Dogs (ADHS RMSF Handbook)

Brand Name	Formula	Active chemical(s)	Length of activity	Cost per dose	Special Safety Instructions	Other notes
Activyl Plus	Topical	Indoxacarb & permethrin	1 month	$8-10*	Not for use on breeding dogs. For use on dogs at least 8 weeks old.	Not safe for use on cats.
Bravecto	Oral	Fluralaner	3 month	$42 ($14 per month)	For use in dogs at least 12 weeks old and at least 4.4 lbs.	No risk for humans.
Ecto Advance Plus	Topical	Fipronil &(S)-methoprene	1 month	$10-15	For use on dogs at 8 weeks old and at least 4 lbs	Waterproof
Effitix	Topical	Fipronil & permethrin	1 month	$6 – 10*	For use on dogs at least 8 weeks old.	Not safe for use on cats. Suspected carcinogen
Frontline plus	Topical	Fipronil and (S)-methoprene	1 month	$10-15	For use on dogs at 8 weeks old and at least 4 lbs	Waterproof
Frontline tritak	Topical	Fipronil, cyphenothrin & (S)-methoprene	1 month	$10-15*	For use on dogs at least 12 weeks old and at least 4 lbs.	Waterproof
Hartz InControl	Topical	Tetrachlor-vinfos	1 month	$5-10	For use on dogs at least 12 weeks old.	Organophos-phate, possible human carcinogen
Hartz Ultra-guard Flea & Tick drops	Topical	Phenothrin	1 month	$5*	For use on dogs at 12 weeks old and at least 4 lbs.	
K9 Advantix II	Topical	Imidacloprid, permethrin & pyriproxyfen	1 month	$10-15	For use on dogs at 7weeks old	Not safe for use on cats. Waterproof
Nexgard	Oral	Afoxolaner	1 month	$20	For use on dogs at 8 weeks old and at least 4 lbs.	Use with caution in dogs with a history of seizures.
Parastar Pet Armor	Topical	Fipronil	1 month	$6	For use on dogs at 8 weeks old and at least 4 lbs	Waterproof
Parastar Plus	Topical	Fipronil & cyphenothrin	1 month	$15-20*	For use on dogs at 8 weeks old and at least 4 lbs.	Waterproof
Vectra 3D	Topical	Dinotefuran, permethrin, pyriproxyfen	1 month	$14	For use on dogs at 8 weeks old and at least 5 lbs.	Not safe for use on cats. Waterproof

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