Transmission Times and Prevention of Tick-Borne Diseases in Dogs*

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ABSTRACT: Increasing evidence indicates that tick infestation can result in the transmission of a broad spectrum of bacterial and protozoal organisms to dogs. Anaplasma, Babesia, Bartonella, Borrelia, Coxiella, Ehrlichia, Hepatozoon, and Rickettsia species are the most important canine tick-transmitted pathogens in the United States. Many of these organisms have evolved so as to facilitate persistent infection, which can be sustained in healthy dogs for months to years before clinical signs are recognized. Although the mechanisms of transmission differ among organisms, there is generally a brief delay in transmission of the organisms after tick attachment. Therefore, a window of opportunity exists during which tick removal or acaricide products may reasonably interrupt transmission.

From an evolutionary perspective, it is obvious that ticks, tick-borne organisms, and animal and human hosts have developed a highly adapted form of interaction. In general, ticks require blood for nutrition; bacterial, rickettsial, and protozoal organisms need a nutritionally rich environment in which to survive and reproduce; and immunologically, dogs appear to be able to support infection with several tick-borne organisms for months to years without the induction of obvious deleterious effects. Because of the persistent nature of many of these intracellular infections, pathologic features may develop slowly or insidiously in animal hosts. Clinically, our current understanding of the factors that transform a chronically infected, healthy dog into an acutely or chronically ill dog is limited. More recent evidence indicates clearly, however, that clinicians should be proactive in their efforts to control tick infestations and thereby minimize the transmission of tick-borne pathogens to dogs.

In North America, hard-bodied, or ixodid, ticks transmit most of the important tick-borne pathogens found in humans and dogs. Several genera belong to this family of ticks, including, but not limited to, *Ixodes*, *Amblyomma*, *Dermacentor*, and *Rhipicephalus*. These ticks have four life cycle stages: egg, larva, nymph, and adult, the last two being the most important for transmitting some disease agents for which ticks serve as vectors must undergo reactivation, migration, or multiplication before transmission to the host.

Some acaricides approved for use in dogs have been shown to help prevent transmission of *Borrelia burgdorferi* and canine monocytic ehrlichiosis; the ability to prevent transmission of other agents is unknown.

Some organisms may be in the activated, infectious state within the tick before transmission to the host occurs; therefore, great care should be taken when removing ticks.

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disease-causing agents to animals. During each life stage, except the egg, these ticks feed on birds, reptiles, or mammals.3–5

**FEEDING PROCESS OF TICKS**

To feed on a host, the tick attaches and inserts a sophisticated feeding apparatus. Saliva is injected during this process to anesthetize the site and to alter the host’s immune or inflammatory response, so as to enable prolonged and successful feeding. During the feeding process, ixodid ticks consume relatively large quantities of blood. The female’s body weight can increase more than 100-fold during a feeding period. To accommodate changes in fluid and electrolyte balance within the tick, saliva is secreted intermittently during the process. Fecal production and regurgitation also occur. It is during salivation and regurgitation that most pathogens are efficiently transmitted. Tick feces and undigested blood wastes are also deposited at the site of attachment during feeding and in some cases appear to serve as an alternative means of transmission of infectious organisms.3–5

Most ixodid ticks require several days to complete the process of blood ingestion. These ticks can then survive months to years without an additional blood meal. Seasonal variation in tick feeding activity accounts for seasonal variation in the acute onset of tick-transmitted diseases.5–5 For organisms that induce chronic infections, which may occur after an acute illness, such as babesiosis, ehrlichiosis, and bartonellosis, a seasonal incidence may be less obvious.

**REQUIREMENTS FOR ORGANISM TRANSMISSION AND INFECTION**

For most tick-transmitted diseases, the organisms are not simply housed on the tick’s mouthparts, ready for immediate inoculation into the next host. Organisms that parasitize ticks must adapt to extremes in physiologic states that they encounter during a tick’s prolonged fasting and feeding to survive and be transmitted to the host. Therefore, a window of opportunity exits during which, if the tick is repelled, detached, or killed, transmission may not occur. Properties of the organism (reactivation requirements, the physical niche it occupies within the tick), the tick (life stage, species, genus, coinfection with multiple agents), the environment (temperature), and the host (species, immune status) may all affect the time it takes for a tick to transmit a specific agent.

For example, a period of pretransmission reactivation accompanied by ultrastructural and physiologic changes has been documented for some vector-borne disease agents, including *Borrelia burgdorferi* (the cause of Lyme disease) and *Rickettsia rickettsii* (the cause of Rocky Mountain spotted fever).6–9 In these instances, the time it takes for the organism to reactivate likely influences the duration of this interventional opportunity.

Evidence exists that some tick-transmitted disease-causing organisms, such as *Rickettsia conorii* (the cause of boutonneuse fever), *B. burgdorferi*, and *Borrelia afzelii* (a cause of European Lyme disease), may be in the activated, infectious state before mechanical disease transmission occurs.10–12 Studies also suggest that organisms need to be in the physical location within the tick (i.e., the salivary glands or ducts) in adequate numbers to be transmitted to, and develop a patent infection in, the host. For example, de Silva and Fikrig,13 in 1995, found *B. burgdorferi* in the midgut and not the salivary glands of unfed *I. scapularis* ticks. In the same year, Piesman14 showed that 19% of unfed *I. scapularis* nymphs harbored *B. burgdorferi* spirochetes. In both studies, the numbers of spirochetes located within tick salivary glands increased dramatically by hour 72 of feeding, probably because of dissemination from the midgut and multiplication of the organism within the salivary glands.13,14 In the latter study, homogenates of the tick salivary glands did not produce infection in mice unless the ticks had fed for 60 hours or more. Similarly, Piesman and Spielman15 could not detect *Babesia microti* organisms (a causative agent of human babesiosis) by microscopic examination of the salivary glands of *I. scapularis* ticks until after 48 hours of feeding, and transmission of the agent to hamsters was much more frequent at 54 hours (50%) than at 36 hours (9%). Therefore, repelling, killing, or physical detachment of the tick before the development of an infectious dose of organisms within the salivary glands might interrupt transmission of some organisms.

In contrast, spotted fever group *Rickettsia* organisms, such as *R. rickettsii*, *R. rhipicephali*, and *R. Canada*, cause disseminated infection in ticks and infect many tissues, including salivary glands.10,16–19 In addition, Santos and colleagues19 demonstrated *R. conorii* organisms in the salivary glands of experimentally infected unfed ticks. These organisms multiplied within the salivary glands during feeding and were ultrastructurally similar in both the unfed and the fed states. A spotted fever group-like *Rickettsia* sp has also been documented in the salivary glands of unfed *Dermacentor taiwanensis* ticks.19 Similarly, *Anaplasma phagocytophilum* (a cause of human and canine granulocytic ehrlichiosis) and *A. phagocytophilum*–like organisms have been shown to reside in the salivary glands of unfed *I. scapularis* and *I. ricinus* ticks.20,21 Organisms that reside in the salivary glands of unfed ticks, if present in an infectious state and in adequate numbers,
would presumably be transmitted more quickly to the host than those that do not. The extent to which currently available acaricides can interrupt the transmission of \textit{Rickettsia} or \textit{Anaplasma} spp is unknown.

**TRANSMISSION TIME**

The idea that these different adaptations by microorganisms to niches within the tick can contribute to differences in transmission time is supported by laboratory evidence showing that transmission times for \textit{B. burgdorferi} and \textit{B. microti} in \textit{I. scapularis} are generally longer than those for \textit{A. phagocytophilum} in \textit{I. scapularis} and \textit{R. rickettsii} in its tick host.\textsuperscript{11,15,22–27} This concept is also supported by studies showing that host immunity to the tick itself can prevent transmission of \textit{B. burgdorferi} but not \textit{A. phagocytophilum} in \textit{I. scapularis}.\textsuperscript{21,28} Therefore, the time frame for intervention, particularly under natural conditions, may be shorter for some pathogens than for others.

**Determination of Minimal Time for Organism Transmission**

Studies examining the minimal time required for disease transmission from tick to host involve only a few tick-borne organisms. Of the pathogens that infect dogs and humans, \textit{Borrelia} spp, \textit{R. rickettsii}, and \textit{A. phagocytophilum} have been studied in the greatest detail. Of these, most data have been collected for \textit{Borrelia} spp. Several laboratory experiments showed that \textit{I. scapularis} nymphs and adults (vectors for \textit{B. burgdorferi} in the eastern United States) only occasionally transmit \textit{B. burgdorferi} organisms before 24 to 48 hours after the initiation of feeding on laboratory animals, but they are very efficient at transmitting the agent if they are allowed to feed for longer periods.\textsuperscript{11,22,23,26} Evidence from a clinical study involving people bitten by \textit{I. scapularis} nymphs supports these experimental studies. Sood et al\textsuperscript{25} documented a significantly higher rate of occurrence of Lyme disease when the duration of attachment was 72 hours or more versus less than 72 hours (20% versus 1.1%, respectively).

**Dependence on Host- and Tick-Related Factors**

The time required for transmission of \textit{B. burgdorferi} spirochetes may vary among tick and host species or developmental stage of the tick. Kahl et al\textsuperscript{29} showed that transmission time for \textit{B. burgdorferi} by \textit{I. ricinus} (a European tick vector for Lyme disease) occurred within 16.7 hours of attachment. In addition to using a different species of tick, this study used the gerbil as the host species; mice, rabbits, or hamsters were used in the \textit{I. scapularis} studies documenting the longer transmission times for \textit{B. burgdorferi}. In 1995, Peavey and Lane\textsuperscript{30} demonstrated that the minimal transmission time to mice for \textit{B. burgdorferi} spirochetes from \textit{Ixodes pacificus} nymphs (which transmit \textit{B. burgdorferi} on the West Coast of the United States) was 48 hours, but they mentioned a clinical report that suggested transmission times to humans were more rapid for adult \textit{I. pacificus}. The authors suggested that this discrepancy might be explained by evidence that \textit{B. burgdorferi} causes septicaemia and is present in the salivary glands of unfed adult \textit{I. pacificus} ticks, thus resulting in more rapid transmission time, or that the hosts involved (mice versus humans) may contribute to the observed differences in transmission times.

Transmission times may also vary with the physiologic state of individual ticks. Partially fed \textit{I. scapularis} ticks, whose initial feeding was interrupted within 24 to 48 hours of attachment, can transmit \textit{B. burgdorferi} spirochetes rapidly (before 24 hours) and at a high frequency (83% to 100%, respectively) after reattaching to a second host.\textsuperscript{31}

**Dependence on Species and Genus of Pathogen**

In addition to variation according to tick- and host-related factors, time to transmission may vary with the species of \textit{Borrelia}. A study by Crippa and coworkers\textsuperscript{12} documented transmission of \textit{B. afzelii} organisms from \textit{I. ricinus} in 14% (one of seven) of mice within 24 hours and 50% (four of eight) within 48 hours, but \textit{B. burgdorferi} was not transmitted to any mice until after 48 hours of feeding by the same tick species.

As mentioned above, pathogens belonging to different genera have transmission times that differ from those of \textit{Borrelia}. Laboratory studies suggest that the time period required for \textit{R. rickettsii} reactivation and transmission to the host by \textit{Dermacentor andersoni} may be less than the time required for the same process for \textit{Borrelia} spp by \textit{Ixodes} ticks. In 1923, Spencer and Parker\textsuperscript{2} showed that unfed \textit{D. andersoni} ticks carrying \textit{R. rickettsii} organisms were not infective for guinea pigs but became infective after a 48-hour period of feeding or incubation at 37°C for 2 to 7 days before attachment. These authors mentioned that they could not show infectivity before 48 hours of reactivation, but that Ricketts, in 1911, reported transmission of \textit{R. rickettsii} organisms within 1.75 to 20 hours.\textsuperscript{7} It should be noted that these studies, although elegant, were conducted many years ago, when transmission was defined by demonstration of the disease or immunity to challenge. To our knowledge, studies using more sensitive methods, such as polymerase chain reaction assay, to investigate transmission times have not been conducted.

Studies investigating the time required for \textit{I. scapularis} to transmit \textit{A. phagocytophilum} organisms to mice
also show variable results. Reported transmission times range from less than 24 hours to greater than 40 hours.\textsuperscript{22,25,27} Variability in the number of infectious organisms carried by individual ticks, the source of the infected ticks, the strain of mouse on which ticks are attached, and the methods used to confirm \textit{A. phagocytophilum} infection could account for the differences among these experimental studies.

**Experimental Versus Field Data**

Collectively, these investigations of the time required for ticks to transmit pathogens illustrate that, although laboratory investigations provide a framework with regard to minimal transmission times, all variables occurring in a natural setting cannot be mimicked, and clinical field studies are needed to complement the laboratory data. These studies also indicate that encountering a tick harboring an infectious agent is not necessarily equivalent to disease transmission. Physical removal or the use of products capable of repelling, detaching, or killing ticks may prevent disease transmission if it is possible to interfere with the tick’s feeding before the window of opportunity is closed.

**PRODUCTS USED FOR KILLING OF TICKS**

Several products have been developed for use on dogs to achieve the goal of rapid and sustained killing of ticks. The reader is referred to original references and product information regarding product efficacy against individual tick species.\textsuperscript{32–36} It should be noted that these investigations differ with regard to the species of ticks, the number of ticks used to infest the dogs, the time to evaluation after tick infestation, the criteria for evaluation, the frequency of product application, and the product formulation, among other variables. These differences make direct comparisons with regard to products used in these studies quite difficult, if not impossible. It is not the purpose of this review to provide a comparison among products. However, some studies have directly compared products under the same experimental conditions, and results from these studies are given in Table 1. The studies of tick attachment within a few hours after infestation evaluated the ability of the product to repel or immediately kill the tick, whereas evaluation after more prolonged postapplication periods tested whether death or detachment occurred by those later time points. The reader is cautioned that although extensive literature searches were performed, this summary may not be all-inclusive.

**Laboratory Investigations Preventing \textit{B. burgdorferi} Transmission**

Although extrapolations can be made from these studies about the potential for products to repel ticks or interrupt their feeding before disease transmission, few studies have directly evaluated the ability of available tick control products to prevent transmission of disease to dogs. An amitraz-impregnated collar (Preventic collar; Virbac), fipronil (Frontline Spray; Merial), and permethrin plus imidacloprid (K9 Advantix; Bayer Animal Health) have all been shown to prevent transmission of \textit{B. burgdorferi} organisms by adult \textit{I. scapularis} ticks in laboratory settings. The amitraz-impregnated collar prevented infection as evidenced by a lack of seroconversion to \textit{B. burgdorferi} in beagles exposed to infected field-caught adult \textit{I. scapularis} ticks 7 days after the collar was applied.\textsuperscript{44} Permethrin plus imidacloprid prevented infection as evidenced by a lack of seroconversion to \textit{B. burgdorferi} when beagles were exposed to infected adult \textit{I. scapularis} ticks 7 days after treatment.\textsuperscript{45} Fipronil prevented transmission of \textit{B. burgdorferi} by adult \textit{I. scapularis} ticks as measured by serology, polymerase chain reaction assay, and culture of skin biopsy specimens.\textsuperscript{46} In this study, transmission was prevented whether ticks were applied 7 or 28 days after treatment.

**Field Study Investigating Canine Monocytic Ehrlichiosis**

These studies demonstrate the ability of these products to prevent \textit{B. burgdorferi} transmission to dogs after one application and limited exposure to a single species of disease-carrying ticks in laboratory settings. To our knowledge, only one study has investigated the efficacy of disease prevention by use of a canine tick control product according to the manufacturer’s instructions in a controlled experiment in a field setting. In this large, year-long, prospective study involving 248 dogs in Africa, the ability of monthly application of fipronil (Frontline Spot-On Chien L, Merial) to prevent transmission of \textit{Ehrlichia canis} organisms by \textit{Rhipicephalus sanguineus} was investigated. Dogs were divided into two treatment groups: French Army dogs living in Djibouti from 4 months to 4 years, and French Army dogs living in Dakar from 4 months to 4 years. Control groups consisted of two groups in Djibouti (native dogs; dogs living with expatriate French citizens), and four groups in Dakar (native dogs; police dogs living in three kennels). Monthly fipronil use resulted in an overall protection rate of 96.4\% for French Army dogs living in this endemic area. Seroprevalence for treated dogs was 2.7\% for dogs in Djibouti and 5.5\% for dogs in Dakar. Seroprevalence in untreated control groups ranged from 21.7\% (in the expatriate dogs in Djibouti) to 100\% (in police dogs in Dakar). No dog treated with fipronil developed an illness that would be compatible with canine ehrlichiosis, whereas mortality...
Table 1. Comparison Studies of Selected Tick Control Products for Use in Dogs<sup>a,b</sup>

<table>
<thead>
<tr>
<th>Treatment&lt;sup&gt;c&lt;/sup&gt;</th>
<th>No. of Treated Dogs</th>
<th>Tick Species (No. of Ticks Applied)</th>
<th>Time of Tick Application</th>
<th>Time from Tick Application to Evaluation</th>
<th>Results</th>
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<tbody>
<tr>
<td>Fipronil (Frontline Top Spot, Merial)&lt;sup&gt;32&lt;/sup&gt;</td>
<td>18</td>
<td><em>Rhipicephalus sanguineus</em> (50) <em>Dermacentor variabilis</em> (50)</td>
<td>Days –2, 13; then weekly to day 48</td>
<td>48 hr after each tick application</td>
<td><strong>Percent efficacy</strong>&lt;br&gt;Day 2: 91.5%&lt;br&gt;Day 29: 98.1%&lt;br&gt;Day 29: 98.4%&lt;br&gt;Day 2: 77.3%&lt;br&gt;Day 29: 90.6%&lt;br&gt;Day 15: 81.8%&lt;br&gt;Day 36: 57.5%&lt;br&gt;<strong>Reduction in tick counts</strong>&lt;br&gt;<em>D. variabilis</em> &gt;95% all time points&lt;br&gt;<em>R. sanguineus</em> &gt;95% all time points&lt;br&gt;<em>D. variabilis</em> &lt;71% all time points&lt;br&gt;<em>R. sanguineus</em> &lt;71% all time points</td>
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<tr>
<td>65% permethrin (Defend EXspot; Schering-Plough Animal Health)&lt;sup&gt;32&lt;/sup&gt;</td>
<td>12</td>
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<td>Untreated controls&lt;sup&gt;32&lt;/sup&gt;</td>
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<tr>
<td>Fipronil (Frontline Top Spot)&lt;sup&gt;37&lt;/sup&gt;</td>
<td>10</td>
<td><em>D. variabilis</em> (50) <em>R. sanguineus</em> (50)</td>
<td>Days 7, 14, 21, 28</td>
<td>48 hr after each tick application</td>
<td><strong>Percent efficacy</strong>&lt;br&gt;Day 2: 96.3%&lt;br&gt;Day 14: 95.9%&lt;br&gt;Day 21: 90.7%&lt;br&gt;Day 35: 91.3%&lt;br&gt;<strong>Reduction in tick counts</strong>&lt;br&gt;<em>D. variabilis</em> Day 2: 99.1%&lt;br&gt;Day 7: 99.0%&lt;br&gt;Day 14: 95.9%&lt;br&gt;Day 21: 88.5%&lt;br&gt;Day 28: 87.1%&lt;br&gt;Day 41: 48%&lt;br&gt;<em>R. sanguineus</em> Day 2: 61.4%&lt;br&gt;Day 7: 51.6%&lt;br&gt;Day 14: 37.0%&lt;br&gt;Day 21: 33.7%&lt;br&gt;Day 28: 10.8%&lt;br&gt;Day 41: 0%</td>
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<td>Selamectin (Revolution; Pfizer Animal Health)&lt;sup&gt;37&lt;/sup&gt;</td>
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<tr>
<td>65% permethrin (Defend EXspot)&lt;sup&gt;38&lt;/sup&gt;</td>
<td>6</td>
<td><em>Ixodes ricinus</em> (50)</td>
<td>Days 2, 7, 14, 21, 28, 28, 35, 41</td>
<td>Immediately after 2 hr of exposure</td>
<td><strong>Percent efficacy</strong>&lt;br&gt;Day 7: 96.3%&lt;br&gt;Day 14: 99.5%&lt;br&gt;Day 21: 90.7%&lt;br&gt;<strong>Reduction in tick counts</strong>&lt;br&gt;Day 2: 99.1%&lt;br&gt;Day 7: 99.0%&lt;br&gt;Day 14: 95.9%&lt;br&gt;Day 21: 88.5%&lt;br&gt;Day 41: 48%&lt;br&gt;Day 28: 87.1%&lt;br&gt;Day 35: 91.3%&lt;br&gt;Day 38: 90.3%&lt;br&gt;Day 41: 0%</td>
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<tr>
<td>65% permethrin (Defend EXspot)&lt;sup&gt;39&lt;/sup&gt;</td>
<td>6</td>
<td><em>I. ricinus</em> (50)</td>
<td>Days 7, 14, 21, 28, 35</td>
<td>Immediately after 2 hr of exposure</td>
<td><strong>Percent efficacy</strong>&lt;br&gt;Day 7: 10.9%&lt;br&gt;Day 14: 13.8%&lt;br&gt;Day 21: 16.4%&lt;br&gt;<strong>Reduction in tick counts</strong>&lt;br&gt;Day 2: 96.3%&lt;br&gt;Day 7: 99.5%&lt;br&gt;Day 14: 99.9%&lt;br&gt;Day 21: 90.7%&lt;br&gt;Day 35: 91.3%&lt;br&gt;Day 38: 90.3%&lt;br&gt;Day 41: 0%&lt;br&gt;Day 28: 16.7%&lt;br&gt;Day 35: 31.1%&lt;br&gt;Day 38: 30.6%&lt;br&gt;Day 41: 0%</td>
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<td>Selamectin (Revolution)&lt;sup&gt;39&lt;/sup&gt;</td>
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<tr>
<td>Untreated controls&lt;sup&gt;39&lt;/sup&gt;</td>
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<tr>
<td>Amitraz-impregnated collar (Preventic, Virbac)&lt;sup&gt;40&lt;/sup&gt;</td>
<td>10</td>
<td><em>R. sanguineus</em> (100)</td>
<td>Day –1</td>
<td>Daily from day 0 to day 7</td>
<td><strong>Percent efficacy</strong>&lt;br&gt;Day 2: 76.9%&lt;br&gt;Day 7: 79.6%&lt;br&gt;Day 14: 90.7%&lt;br&gt;Day 21: 88.5%&lt;br&gt;<strong>Reduction in tick counts</strong>&lt;br&gt;Day 2: 99.1%&lt;br&gt;Day 7: 99.0%&lt;br&gt;Day 14: 95.9%&lt;br&gt;Day 21: 88.5%&lt;br&gt;Day 41: 48%&lt;br&gt;Day 28: 87.1%&lt;br&gt;Day 35: 91.3%&lt;br&gt;Day 38: 90.3%&lt;br&gt;Day 41: 0%&lt;br&gt;Day 28: 16.7%&lt;br&gt;Day 35: 31.1%&lt;br&gt;Day 38: 30.6%&lt;br&gt;Day 41: 0%</td>
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<td>Fipronil (Frontline)&lt;sup&gt;40&lt;/sup&gt;</td>
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</tbody>
</table>

The number of alive fed and dead fed ticks was significantly lower for the amitraz-treated group.
### Table 1 (Continued)

<table>
<thead>
<tr>
<th>Treatment†</th>
<th>No. of Treated Dogs</th>
<th>Tick Species (No. of Ticks Applied)</th>
<th>Time of Tick Application</th>
<th>Time from Tick Application to Evaluation</th>
<th>Results</th>
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<tbody>
<tr>
<td>Amitraz-impregnated collar (Preventic)†</td>
<td>10</td>
<td><em>R. sanguineus</em> (200)</td>
<td>Days 7, 8, 10, 13</td>
<td>Days 8, 10, 13, 18</td>
<td>The number of alive fed ticks was lower and dead unfed ticks was higher for the amitraz-treated group.</td>
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<tr>
<td>Fipronil (Frontline)†</td>
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<tr>
<td>Untreated controls†</td>
<td>10</td>
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<tr>
<td>Amitraz-impregnated collar (Preventic)†</td>
<td>10</td>
<td><em>R. sanguineus</em> (naturally infested on a 2-hr walk)</td>
<td>Day –3, then weekly from days 7–70</td>
<td>Days –3, –2, 2, 3, then weekly from day 7 to day 70</td>
<td>Percent of dogs free of ticks</td>
</tr>
<tr>
<td>Fipronil (Frontline)†</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td>Day 2: 30% Day 3: 60% Day 14: 70% Day 35: 20%</td>
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<tr>
<td>Untreated controls†</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td>Day 2: 100% Day 3: 100% Day 14: 90% Day 35: 80%</td>
</tr>
<tr>
<td>Permethrin plus imidacloprid (K9 Advantix)†</td>
<td>4</td>
<td><em>R. sanguineus</em> (50)</td>
<td>Immediately after 2 hr of exposure</td>
<td></td>
<td>Percent efficacy</td>
</tr>
<tr>
<td>Fipronil plus (S)-methoprene (Frontline Plus; Merial)†</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>Day 3: 98.5% Day 7: 95.4% Day 14: 90.6% Day 35: 85.9%</td>
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<tr>
<td>Untreated controls†</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>Day 3: 25.9% Day 7: 56.8% Day 14: –28.1% Day 35: –21.9%</td>
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<tr>
<td>Permethrin plus imidacloprid (K9 Advantix, Bayer Animal Health)†</td>
<td>15 dogs total were randomly assigned to receive either product or as a control; the breakdown was not available.</td>
<td><em>R. sanguineus</em> (50)</td>
<td>Days 2, 9, 16, 24, 30</td>
<td>24 hr after exposure</td>
<td>Percent efficacy</td>
</tr>
<tr>
<td>Fipronil plus (S)-methoprene (Frontline Plus)†</td>
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<td></td>
<td></td>
<td>Day 3: 98.7% Day 10: 100% Day 17: 88.5%</td>
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<tr>
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<td>Day 3: 100% Day 10: 96% Day 17: 92.5%</td>
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<tr>
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<td>Day 3: 98.7% Day 10: 88% Day 17: 88.5%</td>
</tr>
</tbody>
</table>

†Day 0 is the product treatment day for all studies.
*Mechanisms of action and other information on acaricides have been reviewed.*
†Please see references for details about dosing, administration, formulation, additional trials, evaluation procedures, and definitions.
ranged from 44.4% to 75% in three control groups (police dogs from three kennels in Dakar).47

CONCLUSION

Tick-transmitted diseases are an important cause of morbidity and mortality in dogs and their human companions. Because these pathogenic organisms have adapted to idiosyncrasies implicitly associated with tick transmission, a window of opportunity generally exists between the time the host encounters a tick and the transmission of a disease-causing agent from the tick to the host. During this time, removing, repelling, or causing death or detachment of the tick early in the feeding process can prevent transmission of the disease-causing agents. Several products approved for veterinary use in dogs (Preventic, K9 Advantix, Frontline Spray) have prevented transmission of B. burgdorferi in the laboratory setting. A spot-on Frontline formulation has been shown to help prevent E. canis infections under field conditions. Further laboratory and field studies are needed to define the important role of repellents and acaricides in preventing the transmission of tick-borne infectious agents to dogs.

REFERENCES

3. Parola P, Raoult D: Tick-transmitted diseases are an important cause of morbidity and mortality in dogs and their human companions. Because these pathogenic organisms have adapted to idiosyncrasies implicitly associated with tick transmission, a window of opportunity generally exists between the time the host encounters a tick and the transmission of a disease-causing agent from the tick to the host.


The article you have read qualifies for 1.5 contact hours of Continuing Education Credit from the Auburn University College of Veterinary Medicine. Choose the best answer to each of the following questions; then mark your answers on the postage-paid envelope inserted in Compendium.

1. Which life stages of the ixodid tick are most important in transmitting diseases?
   a. egg and larva
   b. nymph and adult
   c. nymph and egg
   d. egg and adult

2. Which statement is true with regard to tick transmission of disease agents?
   a. Organisms are usually transmitted as soon as the tick inserts its feeding apparatus.
   b. Some organisms may be in the active state within the tick before transmission occurs, so care should be taken when removing ticks.
   c. Saliva is important for transmission of disease agents.
   d. b and c

3. Which statement about transmission of disease agents from tick to host is true?
   a. Properties of the organism, tick, host, and environment all likely influence transmission time.
   b. Some organisms undergo reactivation, multiplication, or migration before being transmitted from tick to host.
   c. There is generally a brief window of opportunity during which repelling, detaching, or killing the tick may prevent disease transmission.
   d. all of the above

4. Most ixodid ticks
   a. require several days to become replete with a blood meal.
   b. feed frequently within each life stage.
   c. feed for short periods.
   d. are referred to as soft-bodied ticks.

5. Which statement is true with regard to the transmission of B. burgdorferi organisms by I. scapularis ticks?
   a. Transmission to laboratory animals increases by about 48 hours.
   b. Transmission may be more rapid if the tick has partially fed on another host.
   c. Transmission times never vary.
   d. a and b
6. Which statement regarding transmission times of tick-borne disease agents is true?
   a. Transmission of *A. phagocytophilum* organisms by *I. scapularis* ticks takes longer than that of *B. burgdorferi*.
   b. Transmission of *A. phagocytophilum* organisms by *I. scapularis* ticks may be faster than that of *B. burgdorferi*.
   c. Using mice as hosts in transmission experiments makes results directly applicable to dogs and humans.
   d. none of the above

7. Which statement concerning studies of products used to repel and kill ticks in dogs is true?
   a. Study methods were standardized, which makes direct comparisons regarding efficacy straightforward.
   b. All important species of ticks were used in all studies, and they responded identically to acaricides and repellents regardless of species.
   c. Studies that evaluated the degree of tick infestation within hours of infestation generally analyzed the ability of the product to repel or immediately kill the tick.
   d. all of the above

8. Which statement is true regarding studies on the use of acaricides in dogs?
   a. In laboratory settings, Preventic collar, Frontline Spray, and K9 Advantix prevent transmission of *B. burgdorferi* spirochetes by *I. scapularis* to dogs.
   b. In a field study, Frontline Spot-On Chien L helped prevent canine monocytic ehrlichiosis.
   c. a and b
   d. none of the above

9. Which statement about tick-transmitted diseases is true?
   a. In North America, ixodid (hard-bodied) ticks transmit most of the tick-borne pathogens infecting humans and dogs.
   b. Dogs can be acutely or chronically infected with tick-borne pathogens.
   c. Clinicians should be proactive in attempting to control tick infestations.
   d. all of the above

10. Which statement about ticks and the diseases that they carry is true?
    a. Pathogens are highly adapted to the ticks they infect.
    b. Ticks act only as fomites for vector-borne disease agents.
    c. Hard-bodied ticks cannot survive long without feeding.
    d. Temperature cannot affect transmission of disease agents from ticks.