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Tick bite prevention and tick removal

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Ticks are small blood feeding ectoparasites with a global distribution. They are important vectors of disease pathogens including rickettsiae, spirochaetes, and viruses. Prevention of tick attachment and rapid removal reduce the risk of contracting tickborne diseases, and there are many recommendations on how to achieve this. This article aims to review the evidence base for tick bite prevention and tick removal strategies.

What is a tick?

Ticks are arachnids and can be divided into two families known as Ixodidae (hard ticks) and Argasidae (soft ticks). Hard ticks have a shield-like scutum on their dorsal side and visible mouthparts that protrude forward. Soft ticks lack a scutum and their mouthparts are located on the underside and are therefore not visible. Hard ticks have a three stage life cycle, comprising larval, nymph, and adult stages, whereas soft ticks have two or more additional nymph stages. Larval hard ticks are typically 0.5 mm long (the size of a poppy seed) and have six legs. Nymphal ticks are about 1.5 mm long and adult unfed ticks are about 3 mm long, although once fed they can enlarge to 11 mm in length (fig 1). Both nymphs and adults have eight legs. Tick coloration varies between species, sexes, and different stages of engorgement. Unfed ticks can range from black to a red-brown colour, but once engorged they can appear light pink, purple, dark red, or grey-blue.[1] Each life stage requires a blood meal and feeding may occur in spring, summer, or autumn. The soft ticks feed for up to several hours, whereas adult hard ticks, if left undisturbed, can feed for up to one week until engorgement is reached. They then detach and moult to the next lifecycle stage.[2]

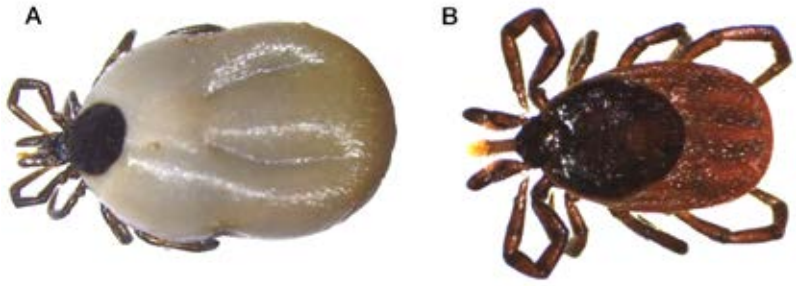

Fig 1 | **(A) Engorged and (B) unfed female adult *Ixodes ricinus* (hard bodied) tick. Reproduced with permission from Public Health England**

SUMMARY POINTS (ADVICE FOR PATIENTS)

- When outdoors check for ticks every 2-3 hours and promptly remove them; self examine the body after being in a tick infested area
- Wear appropriate clothing—long trousers with socks tucked in and shirts tucked into trousers
- Use permethrin treated clothing and a repellent containing PMD or DEET in tick infested areas
- Use fine tipped forceps to remove ticks, grasping the tick close to the skin and pulling steadily without twisting
- If bitten, report symptoms such as rash, unexplained headache, facial palsy, or arthralgia to your GP
- If bitten in a Lyme disease endemic area, consult your GP to discuss antibiotic prophylaxis

SOURCES AND SELECTION CRITERIA

We used PubMed and Google Scholar as search engines. Keywords included ticks, *Ixodes ricinus*, tick removal, tick prevention, tick control, impregnated clothing ticks, repellent ticks, natural repellents ticks, DEET ticks, and DEET *Ixodes ricinus*. We aimed to use papers published in the past 20 years but did not exclude older ones if relevant.

What diseases are spread by ticks?

The most widespread human tickborne disease is Lyme borreliosis, which is commonly transmitted to humans by *Ixodes ricinus*, known as the deer/sheep/castor bean tick. In the United Kingdom, Public Health England (PHE) reported 959 laboratory confirmed cases in 2011 (incidence of 1.73/100 000), compared with 268 cases in 2005 (incidence of 0.50/100 000). In the United States, the Centers for Disease Control and Prevention estimated that 30 000 people were diagnosed as having the disease in 2012.[3]

Several other diseases are caused by tickborne pathogens. Tickborne encephalitis is a viral disease (Flaviviridae virus family) that causes 10 000 cases annually across Europe.[4] Rickettsioses are another group of emerging tickborne diseases caused by obligate intracellular bacteria. They include Rocky Mountain spotted fever (*Rickettsia rickettsii* found in the US), Mediterranean spotted fever (*R conorii* found in the Mediterranean), and African tick bite fever (*R africae* found in sub-Saharan Africa and the Caribbean). Since the 1980s, 12 new rickettsial species and subspecies have been described. Furthermore, a new study showed that pathogenic rickettsiae now occur in British ticks.[5 6] Another emerging tickborne disease is babesiosis, which is caused by haematotropic parasites that infect red blood cells. Several species of babesia can cause disease, including *Babesia divergens*, which causes most European cases,[7] although *B microti* is the most prevalent and is found mainly in the US. Furthermore, a new subspecies of *Borrelia* has recently emerged in the UK (*Borrelia miyamotoi*).

How can tick bites be prevented?

The first step to preventing tick bites is to educate people about ticks and the risks of tick infested areas. One theory based educational randomised controlled trial showed that borrelia infections are reduced in people who receive education about ticks.[8] Other randomised controlled trials that assessed the impact of education and prevention concluded that people who receive education about ticks

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- The diagnosis and management of gastric cancer (*BMJ* 2013;347:f6367)

have greater understanding and change their attitude and behaviour to reflect this.[9 10] Therefore, we recommend that medical practitioners, local authorities, and land owners and managers inform the public through appropriate means, such as information leaflets, posters, websites, and signs.

Which repellents are effective against ticks?

Trans-p-methane-3,8-diol (PMD)

Lemon eucalyptus oil, with the active ingredient *trans-p*-methane-3,8-diol (PMD), is highly repellent against ticks, varying from 100% protection five minutes after application to 85-91% after 48 hours (laboratory studies with rabbits' ears).[11 12] Field studies that compared untreated material and material treated with *Corymbia citriodora* oil and a commercial repellent (MyggA Natural)—both of which contain PMD—found a repellency of 74-85% when dragged over a tick infested area. Repellency lasted for several days, although protection was reduced to 42-45% after three to six days.[12 13] A prospective crossover clinical trial that tested Citriodiol (*cis*-and-*trans*-p-methane-3,8-diol) on volunteers found that the mean number of *I ricinus* ticks attached to each person was 0.5 to people wearing the repellent compared with 1.5 for controls.[14] PMD is recommended and has the advantage that it can be reapplied as often as necessary because it has little to no demonstrated toxicity. One review suggested that PMD should not be used in children under the age of 3 years, but this was largely because of lack of data on younger patients rather than evidence of toxic effects.[15]

N,N-diethyl-3-methylbenzamide and other synthetic repellents

N,N-diethyl-3-methylbenzamide (DEET) is an effective and widely used insect repellent.[16] However, other than laboratory studies, there is little robust evidence for its efficacy against tick attachment. Laboratory studies that tested DEET against several tick species found that DEET can be effective when used in high concentrations (30%), with a repellency of 80-100%; however, the duration was short and varied from two to five hours.[17-21]

Other synthetic repellents, such as Picaridin and IR3535, that have been tested in laboratory trials generally show a lower efficacy than DEET.[20 22] One exception is Ai3-37220 (a piperdine derivative), which had greater repellency than DEET over a six hour test period in a laboratory study.[21]

Laboratory studies show that DEET can be effective at preventing tick attachment, but efficacy is variable and short. These factors should be considered when using DEET. There has been some public concern over the safety of DEET, but those concerns are largely unfounded. Although toxic effects have been seen when DEET is ingested,[15] there is little evidence of risk associated with the use of topically applied DEET. The use of DEET has been implicated in causing seizures in a small number of children under 8 years,[14] but the US Environmental Protection Agency states that the available data do not support a link between DEET and seizures.[23] A double blind randomised therapeutic trial asked pregnant women in their second and third trimesters to apply DEET on a daily basis

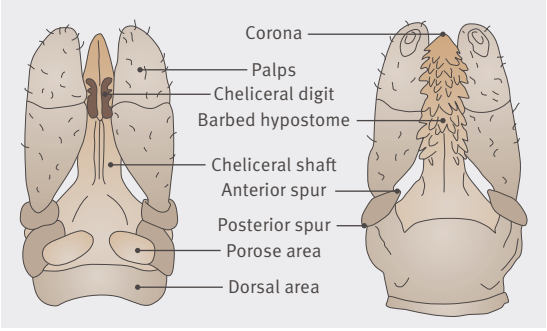

Fig 2 | Diagram of the mouthparts of a hard bodied tick

and found no adverse neurological, gastrointestinal, or dermatological effects. Furthermore, there were no adverse effects on survival, growth, or development of the fetus at birth and one year later.[24] Patients should follow the recommendations of use stated on the label with regard to application rates.

Does protective clothing prevent tick bites?

A simple preventive measure is to wear protective clothing, although this does not guarantee full protection. This includes wearing boots, long trousers tucked into socks, and long sleeved shirts tucked into trousers.[25] Clothing should be checked for ticks every two to three hours during a trip to tick infested areas and for up to one week after returning home because ticks can remain hidden within clothing and attach later.

How effective is permethrin or DEET impregnated clothing?

The use of topically applied repellents is unlikely to achieve 100% coverage because ticks may still attach and move to unprotected skin. Additional protection can be given through the use of clothing impregnated with a toxic active ingredient. Permethrin is a synthetic pyrethroid insecticide commonly used for clothing, tents, and sleeping bags. It has low toxicity, some repellency, and other physiological effects on ticks including "hot feet" and knockdown (where the arthropod is rendered immobile).[26] In two field studies, clothing that had been dipped or sprayed with permethrin provided 100% protection against all life stages (tick species tested included *I dammini* and *Amblyomma americanum*), whereas DEET provided 86-92% protection. Dipping or spraying can be recommended to protect against ticks. Clothing must be retreated every 20 washes to achieve 100% knockdown after 15 minutes of contact time or more often to achieve 100% knockdown in under 15 minutes.[26-28]

The safest and most efficient method is thought to be polymerisation of permethrin into the fibre surface of clothing in the factory.[26] Field studies of clothing treated in this way showed high repellency against ticks, ranging from 93-98%, whereas clothing treated with DEET gave a repellency of 60%. Furthermore, it has a longlasting effect on the fabric and is resistant to washing. In one study, in which impregnated fabric was washed 100 times, 100% knockdown was still achieved with 15 minutes of exposure to *I ricinus* nymphs.[27] One non-randomised open label pilot study that asked outdoor workers to wear permethrin

treated clothing for seven months found a 93% reduction in tick bites compared with controls.[29] Permethrin impregnated clothing is recommended for people who spend prolonged periods of time in tick infested areas.

How do ticks attach and why is removal important?

To begin feeding, ticks cut through the skin using chelicerae and insert a feeding tube, called a hypostome, into the opening (fig 2). The hypostome is covered with backward facing projections, known as denticles, which anchor the tick on to the host. Some species also secrete a cement-like substance from the salivary glands, which hardens around the mouthparts to form a collar that allows the tick to remain firmly in place. Any cement that is left in the skin may cause an allergic reaction or infection.[30] Tick removal is important to prevent the transmission of infectious agents and localised infection from the tick bite.

How quickly should a tick be removed?

Borrelia burgdorferi sensu lato spirochaetes, which cause Lyme disease, reside and replicate in the midgut epithelium of the tick. When a tick attaches, the spirochaetes migrate to the salivary glands and are then transmitted to the host. Laboratory studies have shown that the risk of contracting Lyme disease is low if a tick has been attached for less that 24-36 hours, the time needed for the bacteria to migrate from the midgut to the salivary glands, and that this time frame is crucial in preventing transmission.[31 32] The longer the tick feeds the higher the risk of contracting Lyme disease. However, a laboratory transmission study that gave rodents nymph infected feeds found that transmission occurred within 16 hours.[33] Furthermore, this study showed that ticks infected with *B afzelii* start to transmit infection earlier than ticks infected with *B burgdorferi* sensu stricto, suggesting that there is variation within the species complex. Although the evidence for removing a tick within a specific timeframe is not clear, ticks should be removed sooner rather than later. We strongly recommend the use of an appropriate tool for removal. During prolonged travel in known tick infested areas, it is strongly recommended that people always carry a tick removal tool.

Fig 3 | Correct tick removal with fine tipped forceps; reproduced with permission from Sebastian Kaulitzki

Which methods of removal don't work?

Several methods for tick removal have been proposed that supposedly induce the tick to detach itself from the skin owing to lack of oxygen. These include rubbing petroleum jelly, gasoline, fingernail polish, or 70% isopropyl alcohol over the tick's mouthparts, or placing a lit match next to the tick. None of these methods is effective because ticks have a low respiratory rate.[34] Furthermore, using a lighted match could burn the skin or cause the tick to burst and spread potentially infectious fluids. One state-wide cross sectional study in the US investigated risk factors for *B burgdorferi* antibodies and found evidence that the use of gasoline to remove ticks may increase the risk of *B burgdorferi* infection (odds ratio 4.5, 95% confidence interval 1.2 to 17.6).[35] Some studies argue that the method of tick removal does not influence the risk of transmission of *B burgdorferi*. A laboratory study that used various methods for removal saw no difference in squeezing the tick before removing it and pulling steadily.[31] Another laboratory study found that crushing or gently pulling the tick were both equally effective at stopping transmission within a certain time.[36] These methods are not recommended because they do not promptly detach the tick and may increase the chance of the tick regurgitating its stomach contents, thereby facilitating transmission of pathogens.[37]

How should a tick be removed correctly?

Ticks should be removed using fine forceps by steadily pulling the tick upwards (fig 3). PHE, the NHS, and studies that have examined different methods of tick removal all recommend that fine tipped forceps should be used to grasp the tick as close to the skin as possible and then to pull steadily upwards with an even pressure. They do not recommend twisting or jerking the tick because this may break the mouthparts.[38-41] Furthermore, one study that compared the use of forceps with other methods of tick removal found that forceps protected against *B burgdorferi* and *Rickettsia conorii*. Patients were also protected against infection and complications.[42]

ADDITIONAL EDUCATIONAL RESOURCES

Resources for healthcare professionals

Public Health England (www.hpa.org.uk/Topics/InfectiousDiseases/InfectionsAZ/LymeDisease/GeneralInformation/lym005GeneralInformation/)—Clear information on Lyme disease and links to other useful websites

Public Health England (www.hpa.org.uk/Topics/InfectiousDiseases/InfectionsAZ/LymeDisease/)—Information on Lyme disease, epidemiological data, and Lyme disease diagnostic services in the UK. Patient leaflets and recommendations for diagnosis and treatment across Europe and North America also available

Public Health England (www.hpa.org.uk/Topics/InfectiousDiseases/InfectionsAZ/Ticks/TickPreventionAndRemoval/)—Advice on how to prevent tick bites and minimise ticks in gardens

US Centers for Disease Control and Prevention (www.cdc.gov/ticks/removing_a_tick.html)—Instructions on tick removal, with a diagram

Resources for patients

Borreliosis and Associated Diseases Awareness UK (www.bada-uk.org/)—Clear information on many tickborne diseases found in Europe. All of the information is gathered from scientific resources or research

Patient.co.uk (www.patient.co.uk/health/lyme-disease)—Information on Lyme disease and links to patient support groups and recent articles

Although forceps are considered the best removal method, some specially designed tick removal tools are also available. However, these tools have been studied only in animals and not yet in humans. One study recruited pet owners through veterinarians and asked them to remove ticks from their pets using four different tick removal tools that were randomly assigned using an intervention grid. A total of 236 ticks were removed by both pet owners and veterinarians. The study concluded that people removing the ticks preferred the tick remover tool (O'Tom Tick Twister) over fine tipped forceps because the ticks were easier to grab and quicker to remove. The tool also used less force for extraction and caused less damage to the ticks mouthparts. Another animal study compared three commercially available tick removal tools (Ticked Off, Pro-Tick Remedy, and Tick Plier) against medium tipped forceps. They concluded that the commercially available tools removed nymphs better than forceps because they removed more cement and caused less damage to tick mouthparts. However, nymphs were still more difficult to remove than adults. The authors of this study recommended commercially available tools over medium tipped forceps because they removed nymphs better.[43] More studies assessing the use of these tools in humans are needed before commercial tick removal tools can be recommended in humans. If a person is inexperienced in removing ticks, tools such as these may be an option for ease of use, but we recommend the use of fine tipped tweezers for tick removal until more evidence is available.[44]

What to do after a tick bite?

People who have been bitten by a tick or spent time outdoors in tick infested areas should look for symptoms associated with Lyme disease. About 60% of patients will experience erythema migrans, a localised bull's eye rash.

QUESTIONS FOR FUTURE RESEARCH

Do different tick species have different sensitivities to repellents or insecticides (such as DEET and permethrin)?

How effective are DEET and other repellents in field studies when used on human skin?

How well do commercial tick removal tools work?

Other symptoms are unexplained headaches and neck stiffness, flu-like symptoms, facial palsy, arthralgia, heart palpitations, or dizziness within weeks of the tick bite or exposure.[45 46] People who develop any of these symptoms should notify their general practitioner for a diagnosis and possible treatment. In highly endemic areas, the use of antibiotics can be used as a prophylaxis. A randomised double blind placebo controlled trial found that a 200 mg dose of doxycycline prevented Lyme disease if given within 72 hours of a tick bite.[47]

PHE conducts surveillance of ticks in the UK, and all patients presenting with a tick bite are encouraged to submit the tick to the medical entomology group for identification. It is crucial that tick awareness materials are available within GP surgeries and in nature reserves in areas where ticks are problematic and where Lyme borreliosis is endemic. Understanding the incidence rate of tick bites and erythema migrans across the UK, and how this is changing over time, is now a priority for PHE.

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References are in the version on bmj.com.

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PICTURE QUIZ Sudden onset hair loss and colour change

1 Hair loss can be caused by hair cycle disorders, inflammatory conditions that damage the follicle, or inherited and acquired disorders of the hair shaft. The differential diagnosis for acquired diffuse non-scarring alopecia includes telogen effluvium, underlying medical conditions (such as anaemia, thyroid disease, chronic inflammatory conditions, and infections), drug induced hair loss, and diffuse alopecia areata. Androgenetic alopecia, although classically more localised, should also be considered. In this case, the clinical presentation and histology were most in keeping with diffuse alopecia areata.

2 Laboratory investigations should include full blood count and serum ferritin to identify anaemia and iron deficiency, thyroid function testing, and baseline liver and kidney tests to rule out underlying chronic disease. Diffuse hair loss can be caused by infections such as HIV or syphilis, so high risk patients should be screened.

3 Pigmented hair is preferentially targeted in alopecia areata, whereas white hairs are spared, giving the appearance of colour change. It is thought that this may be due to the presence of antibodies to melanocytes within pigmented hairs.

4 Diffuse alopecia areata can be difficult to treat. Spontaneous regrowth is reported in half of cases. Treatments include topical immunotherapy and intralesional or topical corticosteroids. Because hair loss can be associated with serious psychological morbidity, patients may benefit from support groups such as Alopecia Awareness (www.alopecia-awareness.org.uk) and the prescription of wigs.

STATISTICAL QUESTION Meta-analyses: standardised mean differences

Statement *c* is true, whereas *a*, *b*, and *d* are false.