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Methods of tick removal: A systematic review of the literature

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REVIEW

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ABSTRACT

Background
An increase in tick borne diseases in Australia has seen an interest in appropriate removal of ticks (order Ixodida) in order to prevent anaphylaxis, allergy and transmission of tick borne diseases.

Aims
A systematic review of peer-reviewed literature to determine what method of tick removal should be promoted in terms of preventing future health complications.

Methods
Thematic synthesis was used in two stages: – tick removal studies conducted on animals and humans were examined and the conclusions from all of these studies were compared, in order to ascertain the best tick removal method in relation to prevention of future medical problems (including tick bite allergy and transmission of infection).

Conclusion
This systematic review documents the best method of tick removal based on scientific and medical studies between 1985 and 2016. It concludes that the best method is to remove the tick as soon as possible after it is detected, using either fine-tipped tweezers or a reputable commercially produced tick removal tool to pull the tick away from the site of attachment. Some methods of removal, such as applying chemicals like petroleum jelly, alcohol, or nail polish to the tick, have been discredited. Other methods of removal, such as freezing, while promising, have not yet been scientifically validated.

Key Words
Tick removal, tick-borne, rickettsial infections

What this review adds:

1. What is known about this subject?
There has been an increase in anaphylaxis,[1] mammalian meat allergy[1] and transmission of known infectious diseases following tick bites in Australia[2] leading to an increase in publicly available medical advice regarding tick removal methods, much of which is not based on scientific evidence as no recent studies have been released except those based on clinical observation, rather than clinical trials.

2. What new information is offered in this review?
This review examines the current scientific literature to determine the most effective tick removal methods to ensure positive health outcomes.

3. What are the implications for research, policy, or practice?
This study enables departments of health, employers and community groups to base their tick removal advice on up to date scientific knowledge.

Introduction

Ticks (order Ixodida) are small arachnids that can serve as a vector for the transmission of various infectious diseases. Tick-borne diseases have been identified by the World Health Organisation as one of their priorities for preventable vector-borne diseases.[3] Known tick-borne diseases in Australia include rickettsial infections (including

Queensland tick typhus and Flinders Island spotted fever), ehrlichiosis, babesiosis, and bartonella infections.[4–8] Other negative health outcomes associated with tick bite include tick paralysis (most commonly in children), tick anaphylaxis, and the recently discovered mammalian meat allergy (associated with tick bites).[4] A recent Australian Senate inquiry into Lyme-like illness identified that many Australians are suffering from "chronic debilitating symptoms" which are similar to Lyme disease following a tick bite.[2] The inquiry made twelve recommendations, including "that the Australian Government Department of Health urgently undertake an epidemiological assessment of the prevalence of suspected tick-borne illness in Australia".[2] Recommendation two of the senate inquiry was that "the Australian Government increase funding for research into tick-borne pathogens as a matter of urgency".[2] This is largely as a result of very little work being done in this area in the past twenty years, except for the recent work of Professor Peter Irwin at Murdoch University in identifying novel candidate bacterial species distantly related to known tick-borne pathogens overseas.[9, 10]

Various methods of tick removal are advertised to the public, to physicians and to allied health professionals by different medical bodies, so there is a need to ensure that the tick removal methods advocated are supported by the best scientific knowledge. This paper systematically reviews published studies on tick removal methods, including studies on both humans and animals, to determine what method of tick removal should be promoted in terms of preventing future health complications.

Methods

Three databases, Medline, Pubmed and Embase, were used for the review of the literature on tick removal, using the search terms "tick", "tick-borne" and "removal". All articles published in the last 30 years (i.e., since 1985) were included, and the reference lists of those articles were also examined in an attempt to ensure that no important articles were inadvertently excluded. In order to ensure that the review was as comprehensive as possible, studies on both animals and humans were included, and no distinction was drawn between studies which assessed a wide range of removal methods and those which only tested a single method of removal. However, since the intent of the review was to determine what method of tick removal should be promoted in order to prevent future health complications, reports of single cases were not included in the review as these were viewed as case reports rather than statistically significant studies.

Results and Discussion

A total of 14 articles were identified which met the inclusion criteria. However, two of these articles were essentially identical, being a conference paper and a journal article reporting the results of the same study. Thus 13 (articles are ultimately included in this review of the literature on methods of tick removal, all of them peer-reviewed journal articles (see table 1).

As can be seen in the results quoted in table 1, various studies have demonstrated the ineffectiveness of some methods of tick removal. Ineffective methods can be classified into three broad types; (1) application of chemicals (including gasoline, 70 per cent isopropyl alcohol, fingernail polish and petroleum jelly),[11,12] (2) application of heat,[13] and (3) injection or ingestion of medication (including ingestion of antibiotics and injection of local anaesthetic at the site of the tick bite).[13,14] The main aim of the application of chemicals seems to be to suffocate the tick.[12] Such methods appear to fail due to the low respiratory rate of ticks. Most ticks are also quite resistant to heat, which also explains the failure of the application of heat as a removal method.[12] The amount of heat required to cause serious harm to the tick is likely to also cause serious harm to the patient. There is also evidence to suggest that the application of chemicals or heat may increase the likelihood of anaphylaxis and/or the transmission of tick-borne disease.[1,11,12]

Almost all studies suggest that the most effective methods of tick removal are straight-forward mechanical methods; the use of a commercial tick removal tool, use of fine tipped tweezers or forceps, or the use of a knot in fine fishing line.[15–19] What these mechanical methods have in common is that they all grasp the tick around its mouthparts, rather than around the body, and remove the tick through the use of steadily increasing pressure. All of the experimental trial based studies focussed on considerations of the intactness of the tick after removal, using this as a proxy measure for post-removal medical complications; the greater the chance of the tick being removed intact, the lower the likelihood of post-removal complications of various sorts, including anaphylaxis and the transmission of tick-borne diseases. This is a reasonable assumption, backed up by other supporting evidence, including the 1996 epidemiological study by Oteo et al., which found that removal with tweezers (which tends to remove the tick intact) resulted in significantly less post-removal complications.[17] It is interesting to note that the earliest studies of tick removal techniques all compared simple mechanical methods of removal (i.e., tweezers or forceps) with chemical or heat

based methods, concluding that the mechanical methods were far superior.[11–13,17,19] Later experimental trial based studies all followed standard scientific procedure, comparing other methods of removal (i.e., mechanical tick removal tools of various sorts) to the established medical "best practice" of removal with fine tweezers.[1,14–16,18]

The 2014 paper by Van Nunen et al. is significantly different from all the other studies included in this review, in that it does not eventually recommend a mechanical method of tick removal, instead recommending killing the tick in situ by freezing, which, as the article states, is the method recommended by the Australasian Society of Clinical Immunology and Allergy (ASCIA).[1,20] While the results of the study suggest that the method has promise, there are a number of reasons why this result must be treated with caution. The focus of the study was a narrow one; the prevention of anaphylaxis brought on by tick bite. Whilst anaphylaxis is important in regards to the severity of symptoms, and the Van Nunen article is therefore worthwhile for that purpose, the prevention of tick borne diseases is the primary focus of this review. The World Health Organisation has identified the prevention of vector-borne diseases, including those by tick bite, as a priority, as evidenced by the focus of the WHO World Health Day in 2014 being on the prevention of vector borne diseases such as Lyme disease.[3] One of the limitations of the study that must be considered is that of the 65 patients who removed their own tick only 17/65 (27.6 per cent) used tweezers and only 5/65 (7.6 per cent) used a tick removal tool, whilst the rest were pulled out 27/65 (41.5 per cent), scratched out 9/65(13.8 per cent), or disturbed 6/65(9.2 per cent), methods which are more likely to result in anaphylaxis and transmission of tick-borne diseases.[20] It is also unclear if any of the 65 patients who removed their own tick had been educated in the correct tick removal method prior to removing the tick that caused their anaphylaxis, although it seems unlikely that the 27 patients (41.5 per cent) who pulled out the tick were practicing a recommended tick removal method.[20] Of the 6 patients who removed the tick using the freezing method, it appears that all had received education on the importance of correct tick removal (as they were following recommended ASCIA guidelines). However, how this may have influenced the efficacy of the tick removal method utilised is not discussed.[20] As the study has only been published as an abstract of a poster presentation, it is difficult to fully evaluate the position put forward by Van Nunen et al. regarding the efficacy of the freezing method, but it is an area in which future research is encouraged.

It does seem intuitively plausible that killing the tick almost instantly by freezing it would prevent the transmission of disease. However much more evidence would need to be presented before such a conclusion can be reached. In 2016 Akin Belli published a study which directly compared the freezing method of tick removal against the card detachment, lassoing, and tweezer methods.[21] One hundred and sixty ticks were removed from 160 patients (40 for each method). The results were that the tweezer removal method had a 82.5 per cent success rate, followed by lassoing (47.5 per cent success) and card detachment (7.5 per cent success).[21] The study found that freezing was completely ineffective as a tick removal method, with a 0 per cent success rate (due to the crushing of the tick on removal, which meant that the freezing method (or particular device used) failed one of the study criteria).[21] The Akin Belli study starkly contrasts against the Van Nunen study, which had a 100 per cent success rate.[20,21] Apart from the differences in sample size, the differences between the two studies are that 1) Akin Belli was attempting to limit the transmission of tick-borne diseases and Van Nunen was attempting to limit tick anaphylaxis, and 2) Akin Belli was attempting to kill and remove the tick, whilst Van Nunen was attempting to kill the tick in situ and allow it to spontaneously detach.[20,21]

Materials produced by ASCIA make it clear that they specifically recommend against what they call "common advice" on removal of ticks (i.e., mechanical removal).[1] It is not made clear why this method is referred to in such a manner, rather than as *accepted best medical practice*, which is troubling since mechanical removal is, as the other studies in this review make clear, the method backed by experimental data. It is also the method recommended by leading medical bodies such as the World Health Organisation (WHO)[22] and the U.S. Center for Disease Control (CDC).[23] The ASCIA materials do make it clear, however, that killing the tick in situ by freezing is not a method proven by formal clinical studies, but is rather based on the clinical experience of doctors treating patients with tick allergy.[1] The ASCIA materials also mention that some of the products that they recommend for killing ticks by freezing are "not "registered" for use as therapeutic products for humans".[1] This is not surprising given that the main product they recommend is in fact an automotive spray designed to assist in starting seized and cold engines (and is a product which specifically contains a warning advising users to avoid contact with the skin). However, other products which ASCIA suggest may also be used for the purpose of freezing and killing ticks are designed to be used for medicinal purposes, though again these products

warn against use on exposed skin. Most troubling is the fact that as a result of the ASCIA recommendation for the change in tick removal methods, several community groups in Australia have changed their first aid advice to their members (for example Girl Guides Australia),[25] even though the ASCIA recommendation is ONLY for people with a known tick allergy, and not for the prevention of tick-borne diseases.

Conclusion

The conclusion reached after a systematic review of the published literature on tick removal is that the current accepted medical practice endorsed by the WHO[22] and the CDC,[23] is to remove the tick by mechanical means as soon as possible after the tick is detected. This involves gripping the tick around the mouthparts using either fine-tipped tweezers or a reputable commercially produced tick removal tool to pull the tick away from the site of attachment. The area around the tick bite should then be thoroughly disinfected. Some methods of removal, such as applying chemicals to the tick, or injecting local anaesthetic at the attachment site, have been thoroughly discredited.[11,12] A more recently suggested method of removal, of freezing the tick and allowing it to detach by itself, shows some promise, particularly with regard to preventing anaphylaxis. However more research into this method must be undertaken before it can be considered to be superior to mechanical removal methods.[20] Until further scientific research is conducted, it is recommended that authorities continue to endorse the currently internationally accepted medical practice of mechanical removal of ticks as soon as possible, for people without diagnosed anaphylactic allergies to tick bites.

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PEER REVIEW

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CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

FUNDING

No funding was sought for this study.

ETHICS COMMITTEE APPROVAL

Ethics committee approval was not required as this is a review of the existing published literature.

Figures and Tables

Table 1:

Author, Date	Patient/Study Group	Method	Outcome/Recommendation	Limitations
Akin Belli, A. et al, 2016[22]	160 patients presenting to hospital for tick removal	Patients allocated to groups to test four different removal techniques, being tweezers, and three commercial devices, one each based on freezing, lassoing, and card detachment. Each group included ticks from a range of biological stages (larva, nymph and adult) and physiological situations (newly attached, semi-engorged and engorged). Efficacy of each technique was assessed based on the number of fully detached, non-detached and crushed ticks, and the duration of application required.	Efficacy rates assessed to be 82.5% (33/40) using tweezers; 47.5% (19/40) lassoing; 7.5% (3/40), card detachment; and 0% (0/40), freezing technique. The efficacy rate using tweezers was significantly higher than the other three techniques, so tick detachment using tweezers and cleaning of the bite site was recommended.	Authors note the relatively small sample size and the fact that this was not designed to be a randomised clinical trial. Follow up for post-removal medical complications not discussed.
Van Nunen S., et al, 2014 [21]	78 human sufferers of anaphylaxis from tick bite, and 6 with subsequent tick bite	Retrospective documentation of tick removal techniques employed by tick anaphylaxis sufferers at the time of their tick bite-induced anaphylaxis	Removal method used by 65/78 patients could be determined; none used freezing as a removal technique. 6 subsequent tick bites dealt with using freezing, without provoking anaphylaxis. Killing the tick in situ by freezing was recommended.	Small sample size (only 6 patients used freezing) and initial patients seem largely unaware of medically recommended tick removal techniques. Only interested in reducing anaphylaxis, effect on possible disease transmission not studied.
Sheele J.M., et al, 2014 [15]	10 human subjects each exposed to 24 nymph ticks and 24 adult female ticks	Two ostomy bags, one containing nymph ticks and the other adult female ticks, were attached to human volunteers. 24 hours after attachment, volunteers were given either ivermectin or a placebo. 30 hours later ticks were removed and mortality determined in a double-blinded manner.	Tick mortality in both groups was very high, leading researchers to suspect a toxic exposure, probably due to the glue used to seal the bags. However, the data did not support the conclusion that oral ivermectin is effective in killing attached ticks	Researchers note that the high mortality rate in both active and placebo groups suggests methodological problems. The study was not designed to determine whether ivermectin could prevent the transmission of tick-borne illness

Izutani, K. 2014 [27]	15 human subjects presenting with tick bite	Initial attempts at removal in each case used the commercially available Tick Twister®.	Estimate of time from attachment to removal was significantly shorter in successful removal cases than in unsuccessful ones. Concluded that use of the Tick Twister® is an effective method for early-phase removal of an Amblyomma testudinarium tick.	Small sample size, no apparent follow up for tick borne disease or other medical complications. NB: Article published in Japanese, details here taken from abstract published in English
G. G. Duscher, et al, 2012 [16]	22 veterinarians and 4 experienced pet owners removed 596 attached ticks from various animals	Five commercial tick removal devices with different mechanisms were tested on pets according to their practicability, injury of the mouthparts, and the idiosoma of female Ixodes ricinus ticks. The devices were chosen due to their different methods of grasping the tick and of application of force for removal.	All devices were effective in removing ticks, with very few failures. Tools which grasp the mouthparts and twist for removal produced better results with regard to the level of damage to mouthparts and were thus recommended by this study	Used condition of mouthparts as proxy for post-removal complications - no follow-up for tick borne disease or other medical complications
Ghirga G., Ghirga P., 2009 [17]	17 nymph ticks attached to 10 children	Fishing line tied around the tick mouthparts and slowly tightened to force tick removal. Ticks were studied after removal to determine whether or not they had been entirely removed. Patients were contacted at 1, 2 and 4 weeks post-removal and these calls revealed no patients with concerns for local infections or zoonoses	All ticks were removed alive using the technique, success rate for removing ticks intact was 71%. Study concluded that use of a knot tied in fishing line seems effective, but difficult to apply in hairy areas	Small sample size.
Samsoen M., Molet B., 2004 [19]	30 Ixodes Ricinus ticks (1 larva, 21 nymphs, 8 adult) removed by 26 experienced dermatologists using the Tick Twister® (sold as Tire-Tic in France)	Collective survey of the dermatologists' use of the Tick Twister® provided by the manufacturer.	Users considered the Tool, provided in two sizes, to be easy to use and generally effective for removing all sizes of ticks. 40% of ticks removed with mouth parts entire, 60% had broken mouth parts. Questionnaires show the approximate removal time was 15 seconds, with no pain felt	Small sample size. Used condition of mouthparts as proxy for post-removal complications - no apparent follow-up for tick borne disease or other medical complications. NB: Article published in French, details here taken from abstract published in English

Stewart Jr. R.L., et al, 1998 [20]	148 adult lone star ticks, 82 adult American dog ticks and 112 nymphal lone star ticks removed from laboratory rabbits by untrained individuals	Equal numbers of ticks were removed using (1) tools which close on the mouthparts and pull gently away from the skin, being medium tipped nontissue tweezers and the Tick Plier®, and (2) tools which use a "V" slot to grasp the mouthparts before lifting away from the skin, being the Pro Tick Remedy® and Ticked Off®.	All ticks were able to be removed using the commercial tools, generally with less mouthpart damage than was caused by the tweezers. The three commercial tools were found to be effective in allowing untrained persons to remove both deeply and superficially attached adult ticks as well as nymphal ticks. Medium-tipped tweezers were ineffective for removing nymphs and for this application the commercial tools were superior.	Used condition of mouthparts as proxy for post-removal complications - no follow-up for tick borne disease or other medical complications was attempted
Kahl, O. et al, 1998 [28]	72 Mongolian gerbils exposed to Ixodes Ricinus nymphs taken from a batch highly infected with Borrelia Burgdorferi sensu lato (Bb)	Feeding ticks were divided into 4 groups and removed 16.7, 28.9, 47.0, and 65.2 hrs after attachment. Each group had 3 sub-groups in which ticks were removed by (a) pulling ticks out with forceps without any pre-treatment, (b) pulling ticks out after 3 minutes of intensive squeezing, and (c) applying nail polish to ticks 1.1 hrs before removal. Infection status of each gerbil was then determined by larval xenodiagnosis	100% of gerbils with ticks removed ≥47 hrs post attachment were found to have a Bb infection. 47% of gerbils whose ticks were removed after 16.7 hours feeding were infected, as were 50% of gerbils whose ticks were removed after 28.9 hours of feeding. This study found no evidence that the tick removal method used has any significant influence on Bb infection risk	
Oteo J.A., et al, 1996 [18]	52 patients who presented at hospital for tick removal or post-tick removal treatment	Epidemiological survey of patients who attended hospital for tick bite over 18 months, with follow-up at 1, 2, 4 and 6 months. The aim was to see if tick removal method had any correlation with incidence of tick borne disease	41 patients completed the study with 63.4% experiencing some type of complication, including 3 cases of erythema migrans. Three patients who had ticks removed with tweezers had complications, 23 patients who used other methods had complications. The study concluded that using tweezers	Relatively small sample. No elaboration on "other" methods of tick removal nor discussion of whether this included disinfection. NB: Article published in Spanish, details here taken from abstract published in English

			to remove ticks followed by disinfection of the site of the bite significantly protects from complications	
Lee M.D., et al, 1995 [14]	93 American dog ticks attached to 3 laboratory rabbits (approx. 30 ticks per rabbit)	Three local anaesthetic agents were tested to see if injecting these agents into the skin at the site of tick attachment would cause the ticks to spontaneously detach. The agents were 1% lignocaine (34 ticks), 1% lignocaine with epinephrine (28 ticks), and 1% chloroprocaine (31 ticks).	For each group, after the ticks had been attached for 24 hours, 0.25 mL of anaesthetic was injected subcutaneously under the attached portion of each tick. The technique was found to be ineffective–, with no ticks spontaneously detaching in one hour	Study was not designed to determine whether anaesthetic assisted in prevention of anaphylaxis or transmission of tick-borne illness. The authors also noted that the technique might have been more effective in humans, rather than animals, that a different result might be obtained if ticks had been attached for more or less time, and that ticks might have spontaneously detached if given more time to do so
De Boer R., van den Bogaard A.E., 1993 [12]	Ixodes ricinus ticks attached to the skin of pigs and sheep	Ticks attached to the skin of the animals were exposed to chemicals (gasoline, fingernail polish & methylated spirit) to see if exposure to these chemicals would cause the ticks to either die or spontaneously detach. Two mechanical methods (blunt forceps which require a straight pull away from the skin, and "Tick solution" forceps which rotate the tick out of the skin without pulling) were also tested, both with and without the assistance of the aforementioned chemicals	Chemical methods were found to be ineffective, with no ticks detaching after 30 minutes. The use of chemicals was also found to have no effect on subsequent mechanical removal. Effective straight pull with blunt forceps sometimes completely removed the tick, but often left large mouth piece fragments behind. Twisting with the “tick solution” forceps usually left fragments in the skin, but these fragments were much smaller. Mechanical methods of removal were recommended.	Used condition of mouthparts as proxy for post-removal complications - no follow-up for tick borne disease or other medical complications
Needham G.R., 1985 [13]	Subject was a single Dorset sheep to which 29 American dog ticks attached for 3-4 days, 20 American dog ticks attached for 12-15 hours, and 22 lone star ticks attached for 3 days.	Four American dog ticks of each attachment length were exposed to Petroleum jelly, 70% isopropyl alcohol, fingernail polish and a recently extinguished match to see if any of these methods would cause the tick to die or	Chemical and heat methods were ineffective, with no ticks detaching after 2 hours. 24 dog ticks were subsequently successfully removed intact with forceps, and 5 equally	Used condition of mouthparts as proxy for post-removal complications - no follow-up for tick borne disease or other medical complications

		spontaneously detach. The lone star ticks were all removed with forceps, using different methods; pulling slowly straight up, jerking up from the skin, twisting clockwise, and pulling parallel with the skin.	successfully removed with protected fingers. The lone star ticks were all removed regardless of method, but excreted cement always remained behind. Mechanical methods were recommended, and the author suggests that where the tick is grasped is probably more important than the technique used for removal	