First aid treatment of burn injuries

Cuttle L & Kimble RM

Abstract

The recommendations for the first aid treatment of burn injuries have previously been based upon conflicting published studies and as a result the recommendations have been vague with respect to optimal first aid treatment modality, temperature, duration and delay after which treatment is still effective. The public have also continued to use treatments such as ice and alternative therapies, however there is little evidence to support their use. Recently there have been several studies conducted by burn researchers in Australia which have enabled the recommendations to be clarified. First aid should consist of cool running water (2-15°C), applied for 20 minutes duration, as soon as possible but for up to 3 hours after the burn injury has occurred. Ice should not be used and alternative therapies should only be used to relieve pain as an adjunct to cold water treatment. Optimal first aid treatment significantly reduces tissue damage, hastens wound re-epithelialisation and reduces scarring and should be promoted widely to the public.

Introduction

Throughout history a variety of acute treatments have been used for burn injuries [1, 2], although most of these agents have little or no scientific evidence to support their use. The earliest known record of burn treatment comes from the ancient Egyptian Ebers Papyrus (dated 1500BC) which contains descriptions of applications of mud, excrement, oil and plant extracts on different days after the burn injury has occurred [3, 4] and the application of frogs boiled in oil or of fermenting goat dung [5]. Greek and Roman medicine used dressings impregnated with rendered pig fat, resin and bitumen (Hippocrates, 4th century BC), a mixture of honey and bran followed by cork and ashes (Aulus Cornelius Celsus, ancient Rome) [6], or a lotion of wine and myrrh for burns (1st century AD) [4]. Although Galen (AD 129-199) was credited with the first reported application of cold water for burn treatment, a direct reference to him is unknown. His treatments for most wounds included wine, vinegar and water compresses [4].

Leila Cuttle *

Centre for Children's Burns Research, University of QLD, Queensland Children's Medical Research Institute, Level 4, Foundation Building, Royal Children's Hospital, Herston Rd, Herston, Queensland, Australia, 4029
Tel: +617 3636 9067
Fax: +617 3365 5455
E-mail: L.Cuttle@uq.edu.au

Roy M. Kimble

Centre for Children's Burns Research, University of Queensland, Department of Paediatrics and Child Health, Royal Children's Hospital, Queensland, Australia

* Corresponding author

The relatively modern concept of first aid is believed to have originated from the military battlefield [7], where soldiers were taught how to bandage and splint their wounded comrades. The Prussian Surgeon General Friedrich Von Esmarch is attributed as the earliest to describe first aid (his work was translated into English in 1882) and he recommended that burnt surfaces should be protected from air, and anointed well with oil (lamp oil, salad oil, castor oil or Carron oil from a chemist) or painted over with grease or butter, or powdered with flour, starch or powdered charcoal to alleviate the pain [8]. By 1901, the recommendations for first aid treatment of burns/scalds were clearly segregated depending on wound depth [9], with treatment of flour, whiting or powdered chalk recommended for burns where the skin was "merely reddened", compared to covering with oils (Carron, olive, salad, linseed, almond or cod-liver), Vaseline®, lanoline or cold cream when the skin was blistered or charred. It was not until 1965 that the use of cold water treatment started to appear in St John Ambulance first aid manuals, also with recommendations to not apply any lotions to the burn and for the patient to go to hospital [10]. The manuals stated that the immediate need after a burn injury was to "lessen the spread of heat in the tissues and alleviate pain by immersing the part in cold water if possible (or any other non-flammable fluid to hand), then keep the part dry and clean" [10]. By 1969, guidelines had progressed to irrigation with cold water, followed by cold compresses and then covered with a clean/

sterile cloth [11]. These are the recommendations still promoted by many organisations today.

Current First Aid Recommendations and Published Literature

There are many different recommendations regarding first aid treatment of burn injuries which have been proposed by various regulatory bodies (Table 1). The recommendations all advocate the application of cool or cold tap water (Figure 1), however in most cases they are vague or conflicting with regard to specific temperatures, durations of treatment and delays after which treatment is still effective. Whether or not to use ice or ice water as first aid treatments is also unclear as some recommendations state they deepen the injury and should never be used and others suggest they can be used in a limited manner.

In examining the literature that the recommendations are based upon, there is extensive published work in this area (with the majority conducted in the 1950's and 60's), however most of the studies offer conflicting results due to the different animal models and outcomes used. Very few studies have been conducted in large animal models such as pigs which are more easily translatable to humans [12-14], with the most studies conducted using cheaper rodent models. Rodent wounds heal predominantly via contraction, rather than re-epithelialisation [15, 16] due to the paniculous carnosus muscle layer under the skin and rodents also have thinner skin and increased susceptibility to hypothermia [17]. To test first aid, burns have been created using different modalities (flame, contact, scald) with different depths of damage

Figure 1: The recommendation for the first aid treatment of burns is to apply cold running water to the burn injury, such as water from a household kitchen or bathroom tap.

and unfortunately different studies have examined tissue death or other outcomes at different times, when in burn injuries the cells adjacent to dead tissue can also become necrotic several days after the injury [18]. In terms of outcomes, many measures have been used, such as oedema, clinical appearance, histology and mortality. Very few studies have been conducted for long enough to examine scar formation, although in terms of cosmetic appearance and functionality this is the most important outcome for patients and their doctors. Throughout the field of burn wound research there

Table 1: Recommendations from various organisations concerning the first aid treatment of burn injuries.

Organisation	Recommendation
Red Cross	Lots of cool water for 10 minutes
St John Australian First Aid	Cold running water for 10 minutes or until it returns to normal temperature
ANZBA (Australian and New Zealand Burn Association) [77]	Cool the burn surface with running water at 15°C (or between 8-25°C) for 20 minutes, up to 3 hours after the injury has occurred. Keep patient warm. Do not use ice or iced water.
British Burn Association [78]	Cold (tap) water for 20 minutes, no more to minimize risk of hypothermia, especially in large burns.
International Liaison Committee on Resuscitation (ILCOR) The Consensus on Science for First Aid with Treatment Recommendations (CoSTR) - Thermal Burn: What is the safety, efficacy and feasibility of cooling in the first aid management of a thermal cutaneous burn? [79]	Cool with cold water as soon as possible. Avoid ice or ice water for >10 minutes, especially if burns are large (>20% total body surface area)
Australian Resuscitation Council	Immediately cool the burnt area with cool water for up to 20 minutes, cover with loose non-stick dressing. Do not use ice. Do not apply lotions.

is a need for more longer-term studies to be conducted, in relevant animal models, using appropriate outcome measures.

Do the Public use First Aid?

The inconsistency and confusion within the current guidelines is reflected by the small number of people adhering to them. There have been many studies worldwide examining public use of first aid. The levels of cold water first aid treatment are consistently higher (50-92%) in high-income countries such as Australia and the UK [19-23], compared to regions such as China and Africa, where cold water treatment levels are approximately 10-30% [24-28]. Although the overall use of cold water first aid is higher in Australia, many people are either unaware of the recommendation to apply first aid for a duration of 20 minutes within 3 hours post-burn, or simply have no confidence in this recommendation. In Brisbane, Australia, cold water first aid was found to have been used by 80.2% of paediatric patients – however only 12.1% applied the cold water for 20 minutes or longer [20]. In Sydney, although 92% of children had cold water applied initially to their burn, only 22% received cold tap water for ≥20 minutes duration within 3 hours post-burn [19].

Cold Water Treatment is Beneficial

Cold water treatment has been shown to confer many beneficial effects to the patient and the wound, including; decreased mortality [29-33], pain relief [34], decreased cell damage [35], stabilisation of vasculature [30, 36-40], reduced oedema [41-46], improved wound healing and scar formation [47, 48] and decreased inflammatory response [49-52]. In clinical studies, first aid cooling treatment has also been shown to be associated with improved clinical outcomes such as decreased wound depth, reduced time for wound re-epithelialisation, decreased hospital stay/visits and decreased requirement for grafting and scar management [20, 53-55].

The way in which cold water treatment is applied to the wound appears to be important. A study by Yuan *et al* showed that cool running water applied immediately for 20 minutes duration to porcine burns consistently decreased the histological depth of damage over the course of 9 days compared to wet towels (refreshed every 3 minutes), water spray (delivered every 30 seconds) and an untreated control [48]. To date there have been no studies which test immersion of the burn in cool water compared to treatment with swabs soaked in water, sprays or running water. This would help to determine if the benefit of running water is related to the action of the running water, or if it is simply the presence of a large quantity of continually-refreshing water which is beneficial.

Temperature of First Aid Treatment

Cold tap water is usually applied as first aid, however the temperature of this can vary depending on the time of year and where in the world the tap is located and therefore is it important to know if different temperature treatment influences the wound outcome. Researchers in the literature are divided with regards to the optimal first aid treatment temperature and recommend treatment at either; approximately 0-5ºC [37, 39, 42, 44, 45], 15ºC [30, 40, 43, 56, 57] or 25ºC [17, 58]. The studies which measured large body surface area (BSA) burns or oedema [33, 37, 44] found that lower temperatures such as 5 degrees were optimal, presumably because they promoted vasoconstriction and reduced the amount of fluid loss through leaky vessels post-burn. With large BSA burns, patient mortality is mainly due to hypovolemic shock, and fluid loss from the tissues needs to be replaced by adequate fluid resuscitation management. However, for burns which are not large (i.e. <10% BSA), and there is little risk of patient mortality, wound healing and scarring are more important indicators.

Studies conducted by our group using porcine burns have shown that cold water at 2ºC or 15ºC significantly improved the speed of re-epithelialisation of mid- and deep depth burn injuries and in most cases, decreased the dermal thickness and amount of scarring, as well as improving cosmetic appearance of the scar, compared to untreated controls [47]. Of the two different temperature treatments, the 2ºC treatment lead to slightly better outcomes overall and slightly better outcomes for deeper burns compared to more superficial depth burns. The work of others [35, 42] also indicates that ice water (2ºC) may be a very effective first aid treatment for improving healing of the burn wound, with ice cold water treated burns displaying overall less damage compared to untreated controls with retention of the epidermis, less oedema in the dermis and preservation of cytoplasmic membranes and capillary architecture.

Although ice water may be more beneficial for wound outcome, there are greater risks of hypothermia for patients, especially if the burn area is large and the rest of the patient is not kept warm during treatment. Ofeigsson's classic studies which recommend approximately 25°C water treatment were conducted using rodents with 20% BSA burns which were submerged up to their axilla in the cold water treatment. Ofeigsson found that cold shock from the water caused high mortality (82%, compared to 60% for controls) and advocated treatment at 22-25°C to limit hypothermia and cold shock, whilst still providing protection from damage and reduction in infection compared to controls [58]. He recommended a short immersion of 1-3 minutes at 25°C, followed by immersion at 30°C for 30 minutes [17]. A repeat of these studies testing higher temperatures in a more relevant animal model are certainly warranted to determine if warmer water is as effective as cold or ice water in improving wound outcome for small burns.

Ice Treatment is Not Beneficial

The use of ice to treat burn injuries has been a contentious issue, with early clinical reports advocating its use [59], whereas other reports state that ice can damage tissue or lead to

frostbite [60]. In the study by Sawada *et al*, the application of 16°C tap water for 1 minute was compared to an ice cube applied for 10 minutes. When applying ice, the pressure of application may be important as the combination of pressure and cold has been reported to cause tissue damage [61]. In the studies conducted by our group (where granular ice was placed on top of the wound), the ice gave no benefit to wound healing compared to an untreated control [47]. Although early biopsies were not collected to confirm there was no wound damage created by the ice, there is also no clinical evidence from studies of patients presenting to our hospital that those who had applied ice to their burns suffered from frostbite injuries [20]. However ice does not appear to be as effective as running water on the healing burn wound.

Duration of First Aid Treatment

Previously there has been a lot of conflicting information in the literature regarding the optimal duration and delay of first aid treatment. As first aid treatment is often applied only to relieve pain, the preferred duration of the treatment may be until no pain is felt on removal of the cold [34, 62] – which can be for up to several days [59]! However, researchers have recommended durations of 30 minutes [63], 2 hours [44] or 30 minutes – 3 hours [36]. Recently, Bartlett *et al* found that tap water treatment of porcine burns for 20 minutes showed statistically less histological damage 9 days post-burn compared to 5, 10 and 30 minutes duration [64]. This is in agreement with our own studies which showed that wound re-epithelialisation was faster (p=0.05) after 20 minutes of first aid treatment compared to untreated controls [65]. Interestingly, for both studies, longer durations of first aid treatment (30 minutes or 1 hour) did not provide any further benefit, perhaps indicating that first aid should only be applied for 20 minutes and if pain persists after this time, other analgesics such as paracetamol should be administered.

Delay After Which First Aid Treatment is Still Effective

Although immediate first aid treatment is often recommended (predominantly for pain relief), there is a lot of controversy concerning how long the delay can be before treatment commences and still be beneficial. In the literature, delays after which positive effects can still be seen are reported as; <2 minutes [41], <5 minutes [30, 66], <30 minutes [36], 30 minutes [67, 68], 45 minutes [17], <60 minutes [33], 60 minutes [69], 2 hours [45] or 3 hours [43]. More recently, studies by Rajan *et al* showed in a porcine burn model that the protective effect on tissue histology given by immediate treatment was still seen after a 1 hour delay of treatment [69]. Studies by our group have also shown that delayed treatment of a porcine burn for 1 or 3 hours still improves wound re-epithelialisation and decreases the amount of scar tissue compared to untreated controls [65].

However immediate treatment of the burn injury was still the most beneficial in improving wound outcome.

Our studies also demonstrated that the positive effect of recommended first aid (20 minutes duration applied immediately) on re-epithelialisation disappeared after 2 weeks post-burn [65]. After this point, healing was similar to that seen for the untreated controls. This short-term effect would indicate that more superficial burns would benefit more greatly from first aid compared to deep burns as they would be healed within this timeframe. The beneficial effect of first aid appears to be mild compared to other burn treatments that we have measured previously, such as wound dressings [70, 71]. This would suggest that the clinical management of a wound (in hospital) plays a much more important role in the wound outcome than first aid treatment, illustrating that if a burn is anything more than superficial in depth, patients should present to the hospital for appropriate treatment.

Hydrogels and Alternatives

Clinical studies of patients presenting to our hospital found that Burnaid® (Rye Pharmaceuticals, Roseville NSW, Australia) dressings had been applied to 13% of patients before presentation [20]. Burnaid® is one of the tea tree oil hydrodressings available on the market today (along with BurnShield®, Burnfree® and Water-Jel®), which are all quite similar in composition. Other centres have also reported high use of hydrogels with 37% of UK fire brigades found to have used water gel dressings instead of cold water and 76% found to have applied water gel dressing after water treatment [72]. The widespread use of such dressings (which have now even penetrated the first aid kit market) is alarming considering the lack of studies which support their use. Studies have shown that Burnaid® has no antibacterial activity against common burn pathogens such as *P. Aeruginosa* and *E. Faecalis* [73] and allergic contact dermatitis to oxidised tea tree oil is sufficiently common in Australia (prevalence of 1.8-4.8%) to warrant concern [74]. Studies by our group found that the application of Burnaid® to deep dermal porcine burns provided no beneficial healing (in terms of duration of wound healing, histology of the scar or cosmetic appearance) compared to untreated controls [75]. The dressing was only applied for a short period (20 minutes), whereas it has shown potential benefit when applied for 1 hour duration in an observational study, which contained no statistical analysis [57]. Burnaid® dressing is a very effective evaporative cooling agent (which may give it analgesic properties), however this unfortunately increases the risk of hypothermia in patients with large BSA burns [75]. Another issue is that the viscous residue from the dressing can make monitoring patients difficult when they arrive at hospital emergency, especially if a large amount of dressing was applied. For these reasons, we have advised QLD Ambulance that Burnaid® dressing should not be applied to adults with >20%BSA burns and children with >10%BSA burns.

Figure 2: Aloe vera plant, often used as a home-remedy treatment to relieve the pain of burn injuries. The pulp from insde the leaves is applied directly to the burn or commercial ointments containing pulp extracts are used.

Aloe vera as either the leaf pulp directly from the plant (Figure 2) or a gel treatment containing the pulp is another commonly applied alternative dressing used by the public for burns [20]. Previously, the published data on trials of Aloe vera treatment suggest that it would possibly be of more benefit for superficial burns, rather than deep burns [76]. That opinion is supported by our research, as we found that that the application of Aloe vera for 20 minutes provided no beneficial healing for deep porcine burns [75]. As most people continually apply Aloe vera pulp for several hours post-burn, it is possible that a longer application may have provided some healing benefit, however the main effect of alternative treatments such as Aloe vera and Burnaid® appears to be their ability to reduce or eliminate pain, rather than improve wound healing.

Updated Recommendations for First Aid Treatment (Table 2)

First aid should consist of cold running water, applied as soon as possible after the burn injury has occurred and for 20 minutes duration as this treatment has been shown to significantly reduce tissue damage, improve wound re-epithelialisation, and decrease scarring. As cold water at 2°C and 15°C were both beneficial, cold water from the tap should be effective, even in colder parts of the world. Ice should not be used for first aid as there is no evidence it improves the wound outcome, whereas cold running water does provide benefit. Alternative treatments such as Aloe vera and Burnaid®/hydrogels do not appear to give beneficial wound healing effects and may only provide analgesia. Their use should be limited to providing analgesia after initial cold water treatment, or to provide analgesia until running water can be applied, which may be up to 3 hours after the injury has occurred. Professional medical attention

Table 2: Summary of the updated recommendations to the public concerning the optimal first aid treatment.

Updated Recommendations for the First Aid Treatment of Burns

Treatment	Cold running water
Temperature	Tap water (2-15°C)
Duration	20 minutes is best, 10 minutes - 1 hour is acceptable
Delay	Immediate is best, 1-3 hours is acceptable

should be sought for burns involving the face, genitals, perineum or hands, or for burn areas larger than a 50c coin (3cm diameter circle). Attention should also be sought for any burns which appear white or chalky, with decreased pain sensation (deep burns) or if there is evidence of an inhalation injury (e.g. soot or smoke residue around nose or mouth). When using cold water, be wary of hypothermia, especially with small children or patients with large body surface area burns, and only treat the burn area, while keeping the rest of the patient warm if possible.

References

1. Pinnegar MD, Pinnegar FC, 3rd. History of burn care. A survey of important changes in the topical treatment of thermal injuries. Burns Incl Therm Inj. 1986 Oct;12(7):508-17.
2. Rosenberg L, Mahler D. Folklore-medicine and burns. Burns. 1980;7(4):275-85.
3. Nunn JF. Ancient Egyptian Medicine. London: British Museum Press; 1996.
4. Majno G. The Healing Hand - Man and Wound in the Ancient World. Cambridge: Harvard University Press; 1975.
5. Haeger K. The illustrated History of Surgery. London: Harold Starke (Medical); 1998.
6. Artz CP. History of burns. In: Artz CP, Moncrief, J.A., Pruitt, B.A., editor. Burns a team approach. Philadelphia, PA: W.B. Saunders Company; 1979.
7. Pearn J. The earliest days of first aid. BMJ. 1994 Dec 24-31;309(6970):1718-20.
8. Esmarch F. First Aid to the Injured. Five Ambulance Lectures. (translated by HRH Princess Christian). 1st ed. London: Smith, Elder and Co.; 1882.
9. Cantlie J. First Aid to the Injured. 5th ed. London: St John Ambulance Association; 1901.
10. St John Ambulance Association. First Aid. Manual of St John Ambulance Association, the St Andrew's Ambulance Association and the British Red Cross Society. 2nd ed.; 1965.
11. St John Ambulance Association. First Aid. Manual of St John Ambulance Association, the St Andrew's Ambulance Association and the British Red Cross Society.; 1969.
12. Meyer W, Schwarz R, Neurand K. The skin of domestic mammals as a model for the human skin, with special reference to the domestic pig. Curr Probl Dermatol. 1978;7:39-52.
13. Montagna W, Yun JS. The skin of the domestic pig. J Invest Dermatol. 1964 Jul;42:11-21.
14. Sullivan TP, Eaglstein WH, Davis SC, Mertz P. The pig as a model for human wound healing. Wound Repair Regen. 2001 Mar-Apr;9(2):66-76.
15. Aksoy MH, Vargel I, Canter IH, Erk Y, Sargon M, Pinar A, et al. A new experimental hypertrophic scar model in guinea pigs. Aesthetic Plast Surg. 2002 Sep-Oct;26(5):388-96.
16. Montandon D, D'Andiran G, Gabbiani G. The mechanism of wound contraction and epithelialization: clinical and experimental studies. Clin Plast Surg. 1977 Jul;4(3):325-46.
17. Ofeigsson OJ. Water cooling: First-aid treatment for scalds and burns. Surgery. 1965 Mar;57:391-400.
18. Lawrence JC, Bull JP. Thermal conditions which cause skin burns. Engng Med. 1976;5(3):61-3.
19. McCormack RA, La Hei ER, Martin HC. First-aid management of minor burns in children: a prospective study of children presenting to the Children's Hospital at Westmead, Sydney. Med J Aust. 2003 Feb 6;178(1):31-3.
20. Cuttle L, Kravchuk O, Wallis B, Kimble RM. An audit of first-aid treatment of pediatric burns patients and their clinical outcome. J Burn Care Res. 2009 Nov-Dec;30(6):1028-34.
21. Rea S, Wood F. Minor burn injuries in adults presenting to the regional burns unit in Western Australia: a prospective descriptive study. Burns. 2005 Dec;31(8):1035-40.
22. Matthews RN, Rauf KG, Warren J. The Coventry thermal injury study. Burns. 1991 Feb;17(1):33-6.
23. Rawlins JM, Khan AA, Shenton AF, Sharpe DT. Epidemiology and outcome analysis of 208 children with burns attending an emergency department. Pediatr Emerg Care. 2007 May;23(5):289-93.
24. Yongqiang F, Yibing W, Dechang W, Baohua L, Mingqing W, Ran H. Epidemiology of hospitalized burn patients in Shandong Province: 2001-2005. J Burn Care Res. 2007 May-Jun;28(3):468-73.
25. Tian J. Survey of cold therapy burn patients received. Chin J Burns. 2004;20:305.
26. Tse T, Poon CH, Tse KH, Tsui TK, Ayyappan T, Burd A. Paediatric burn prevention: an epidemiological approach. Burns. 2006 Mar;32(2):229-34.
27. Forjuoh SN, Guyer B, Smith GS. Childhood burns in Ghana: epidemiological characteristics and home-based treatment. Burns. 1995 Mar;21(1):24-8.
28. Olaitan PB, Iyidobi EC, Olaitan JO, Ogbonnaya LS. Burns and scalds:first aid home treatment and implications at Enugu, Nigeria. Annals of burns and fire disasters. 2004;17(2):61-3.
29. Rose HW. Initial cold water treatment for burns. Northwest Med. 1936;35(7):267-70.
30. Reynolds LE, Brown CR, Price PB. Effects of local chilling in the treatment of burns. Surg Forum. 1956;6:85-7.
31. King TC, Zimmerman JM, Price PB. Effect of immediate short-term cooling on extensive burns. Surg Forum. 1962;13:487-8.
32. King TC, Price PB. Surface cooling following extensive burns. Jama. 1963 Feb 23;183:677-8.
33. Poy NG, Williams HB, Woolhouse FM. The alteration of mortality rates in burned rats using early excision, homografting and hypothermia, alone and in combination. Plast Reconstr Surg. 1965 Feb;35:198-206.
34. Shulman AG. Ice water as primary treatment of burns. Simple method of emergency treatment of burns to alleviate pain, reduce sequelae, and hasten healing. JAMA. 1960 Aug 27;173:1916-9.
35. Ofeigsson OJ. Observations and experiments on the immediate cold-water treatment for burns and scalds. Br J Plast Surg. 1959;12:104-19.
36. King TC, Zimmerman JM. First-aid cooling of the fresh burn. Surg Gynecol Obstet. 1965a Jun;120:1271-3.
37. King TC, Zimmerman JM. Optimum temperatures for postburn cooling. Arch Surg. 1965b Oct;91(4):656-7.
38. Wilson CE, Sasse CW, Musselman MM, McWhorter CA. Cold Water Treatment of Burns. J Trauma. 1963 Sep;39:477-83.
39. Saranto JR, Rubayi S, Zawacki BE. Blisters, cooling, antithromboxanes, and healing in experimental zone-of-stasis burns. J Trauma. 1983 Oct;23(10):927-33.
40. Wiedeman MP, Brigham MP. The effects of cooling on the microvasculature after thermal injury. Microvasc Res. 1971 Apr;3(2):154-61.
41. Demling RH, Mazess RB, Wolberg W. The effect of immediate and delayed cold immersion on burn edema formation and resorption. J Trauma. 1979 Feb;19(1):56-60.
42. de Camara DL, Raine T, Robson MC. Ultrastructural aspects of cooled thermal injury. J Trauma. 1981 Nov;21(11):911-9.
43. Shulman AG, Wagner K. Effect of cold water immersion on burn edema in rabbits. Surg Gynecol Obstet. 1962 Nov;115:557-60.
44. Jakobsson OP, Arturson G. The effect of prompt local cooling on oedema formation in scalded rat paws. Burns Incl Therm Inj. 1985 Nov;12(1):8-15.
45. Courtice FC. The effect of local temperature on fluid loss in thermal burns. J Physiol. 1946 Jan 15;104(3):321-45.

46. Manson AD, Williams HB, Woolhouse FM. Correlation of Edema Formation, Hemoconcentration, and Mortality in Experimental Burns Treated with Hypothermia. Surg Forum. 1964;15:469-71.
47. Cuttle L, Kempf M, Kravchuk O, Phillips GE, Mill J, Wang X-Q, et al. The optimal temperature of first aid treatment for partial thickness burn injuries. Wound Repair Regen. 2008;16(5):626-34.
48. Yuan J, Wu C, Harvey JG, Holland AJ, Martin HC, La Hei ER, et al. Assessment of cooling on an acute scald burn injury in a porcine model. J Burn Care Res. 2007 Apr 10.
49. Boykin JV, Jr., Eriksson E, Sholley MM, Pittman RN. Cold-water treatment of scald injury and inhibition of histamine-mediated burn edema. J Surg Res. 1981b Sep;31(2):111-23.
50. Boykin JV, Jr., Crute SL. Mechanisms of burn shock protection after severe scald injury by cold-water treatment. J Trauma. 1982 Oct;22(10):859-66.
51. Heggars JP, Robson MC, London MD, Raine TJ, Becker BJ. Cooling and the prostaglandin effect in the thermal injury. JBCR. 1982;3(6):350-4.
52. Armstrong D, Mills GL. The reversible cold-induced activation of the human plasma kinin-forming system between 37^0 and 0^0C. J Physiol. 1965;179(Suppl):89P.
53. Nguyen NL, Gun RT, Sparnon AL, Ryan P. The importance of immediate cooling--a case series of childhood burns in Vietnam. Burns. 2002 Apr;28(2):173-6.
54. Skinner A, Peat B. Burns treatment for children and adults: a study of initial burns first aid and hospital care. N Z Med J. 2002 Oct 11;115(1163):U199.
55. Tung KY, Chen ML, Wang HJ, Chen GS, Peck M, Yang J, et al. A seven-year epidemiology study of 12,381 admitted burn patients in Taiwan--using the Internet registration system of the Childhood Burn Foundation. Burns. 2005 Jan;31 Suppl 1:S12-7.
56. Demling RH, Mazess RB, Witt RM, Wolberg WH. The study of burn wound edema using dichromatic absorptiometry. J Trauma. 1978 Feb;18(2):124-8.
57. Jandera V, Hudson DA, de Wet PM, Innes PM, Rode H. Cooling the burn wound: evaluation of different modalites. Burns. 2000 Jun;26(3):265-70.
58. Ofeigsson OJ. First-aid treatment of scalds and burns by water cooling. Postgrad Med. 1961 Nov;30:330-8.
59. Earle J. An essay on the means of lessening the effects of fire on the human body. London: C.Clarke; 1799.
60. Sawada Y, Urushidate S, Yotsuyanagi T, Ishita K. Is prolonged and excessive cooling of a scalded wound effective? Burns. 1997;23(1):55-8.
61. Safford FK, Jr., Nathanson MB. Clinical observations on tissue temperatures. Arch Surg. 1944;49:12-22.
62. Sorensen B. First aid in burn injuries: treatment at home with cold water. Mod Treat. 1967 Nov;4(6):1199-202.
63. Blomgren I, Eriksson E, Bagge U. Effect of cold water immersion on oedema formation in the scalded mouse ear. Burns Incl Therm Inj. 1982 Oct;9(1):17-20.
64. Bartlett N, Yuan J, Holland AJ, Harvey JG, Martin HC, La Hei ER, et al. Optimal duration of cooling for an acute scald contact burn injury in a porcine model. J Burn Care Res. 2008;29(5):828-34.
65. Cuttle L, Kempf M, Liu P-Y, Kravchuk O, Kimble RM. The optimal duration and delay of first aid treatment for deep partial thickness burn injuries. Burns (2009), doi:10.1016/j.burns.2009.08.002
66. Allen FM, Safford FK, Jr. Experiments on local hypothermia for treatment of burns and frostbite. Arch Surg. 1950 Sep;61(3):515-23.
67. Venter TH, Karpelowsky JS, Rode H. Cooling of the burn wound: the ideal temperature of the coolant. Burns. 2007 Nov;33(7):917-22.
68. Raine TJ, Heggers JP, Robson MC, London MD, Johns L. Cooling the burn wound to maintain microcirculation. J Trauma. 1981 May;21(5):394-7.
69. Rajan V, Bartlett N, Harvey JG, Martin HC, La Hei ER, Arbuckle S, et al. Delayed Cooling of an Acute Scald Contact Burn Injury in a Porcine Model: Is it Worthwhile? J Burn Care Res. 2009 Jun 5.
70. Cuttle L, Naidu S, Mill J, Hoskins W, Das K, Kimble RM. A retrospective cohort study of Acticoat versus Silvazine in a paediatric population. Burns. 2007 Sep;33(6):701-7.
71. Cuttle L, Mill J, Kimble RM. Acticoat™: A cost-effective and evidence-based dressing strategy. Burns. 2008c Jun;34(4):578-9.
72. Walker A, Baumber R, Robson B. Pre-hospital management of burns by the UK fire service. Emerg Med J. 2005 Mar;22(3):205-8.
73. Faoagali J, George N, Leditschke JF. Does tea tree oil have a place in the topical treatment of burns? Burns. 1997 Jun;23(4):349-51.
74. Rutherford T, Nixon R, Tam M, Tate B. Allergy to tea tree oil: retrospective review of 41 cases with positive patch tests over 4.5 years. Australas J Dermatol. 2007 May;48(2):83-7.
75. Cuttle L, Kempf M, Kravchuk O, George N, Liu P-Y, Chang HE, et al. The efficacy of Aloe vera, tea tree oil and saliva as first aid treatment for partial thickness burn injuries. Burns. 2008 Jul 4;34(8):1176-82.
76. Maenthaisong R, Chaiyakunapruk N, Niruntraporn S, Kongkaew C. The efficacy of aloe vera used for burn wound healing: a systematic review. Burns. 2007 Sep;33(6):713-8.
77. The Australian and New Zealand Burn Association. Emergency management of severe burns manual. 13th ed.; 2009.
78. Lawrence JC. British Burn Association recommended first aid for burns and scalds. Burns Incl Therm Inj. 1987 May;13(2):153.
79. First Aid Science Advisory Board Evidence Evaluation Conference 2005. 2005 International Consensus Conference on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Part 10: First Aid. Circulation. 2005;112((22 Suppl)):III115-25.