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Cooling the burn wound: evaluation of different modalites

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Abstract

A study was undertaken to investigate the cooling and healing effect of different modalities: Melaleuca Alternifolia Hydrogel (Levtrade International (Pty) Ltd.) was compared with tap water as a coolant following application onto a fresh deep partial thickness hot water burn in a porcine model. Four identical circular scalds were created on the backs of 10 pigs. One wound was not treated and served as a control. The other 3 wounds were either cooled with tap water (15°C) or had Melaleuca Hydrogel dressing applied immediately, or after a 30 min delay. Intradermal temperatures were monitored in all wounds: preburn, during the burn and at regular intervals for 1 h. The wounds were biopsied for histological assessment. These samples were repeated at 24 h and 3 weeks. The mean decrease in final temperature at 1 h was in comparison to the preburn temperature; control +0.44°C (i.e. a temperature increase); water −7.82°C; Melaleuca Hydrogel −3.87°C; Melaleuca Hydrogel after 30 min delay −2.67°C. Clinical and histological assessment at 21 days indicated more rapid healing in both the Melaleuca Hydrogel and water-cooled burns compared with the untreated controls.

Effective cooling of the burn wound and an increased rate of wound healing was achieved by both repeated tap water compresses and by immediate or delayed application of Melaleuca Hydrogel. Cooling is an effective means to reduce tissue damage and increase wound healing.

Keywords: Burns; First aid; Cooking

1. Introduction

Cooling the burn wound has been used empirically for centuries in an attempt to reduce pain and decrease mortality [1]. Ordinary tap water is recommended by the British Burn Association as the treatment of choice for the first aid management of burns and scalds [2]. However, the best method and the ideal temperature required to achieve cooling are unknown, as the published data regarding cooling is both confusing and sometimes even contradictory.

This is largely because different animals or models have been used in experimentation, different depths of burn wounds have been created and different criteria have been used to assess outcome [3–7].

Melaleuca Alternifolia Hydrogel is a new commercial dressing designed for the acute treatment of burns [8,9]. By composition it contains 96% water, melaleuca alternifolia oil and emulsifiers at a pH 5.5–7. The hydro-gel is impregnated within a thin layer of foam and presented sterile in different size sheets within sealed aluminium packets. It has a turpentine-like odour.

This study was undertaken to investigate the cooling effect of different modalities on the burn wound and to assess their effect on wound healing. The melaleuca oil was compared with tap water at 15°C in a controlled deep partial thickness burn created on the back of a porcine model [3].

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2. Materials and methods

Four identical burns measuring 90 mm in diameter were created para-sagittal on the backs of 10 consecutive anaesthetised Landrace large white pigs (mean weight = 28.1 kg). The relatively large size of the animal allowed for each of the four wounds to be treated differently and thus each animal could serve as an independent experimental model.

General anaesthesia was administered using sodium thiopentone and halothane gas. The pigs were intubated and the internal jugular vein cannulated to provide venous access. Buprenorphine hydrochloride (Temgesic) was given regularly (6–12 h) for 48 h as intravenous analgesia.

The backs of the pigs were shaved and covered with a protective layer of hydrocolloid dressing ("Granuflex", Convatec, Squibb Laboratories) except for 4 holes of identical size (90 mm in diameter), which were placed paraspinal, 2 on each side.

The deep partial thickness burns were created by exposing the individual sites to 450 ml of water at 82–85°C for 10–12 s. This was done by taping a bottomless jug with the same diameter as the burn site to each wound which was removed rapidly after the prescribed burn time.

The intradermal temperatures were monitored using a Fluke 52 K/J thermometer with four thermocouples. The thermocouples were inserted 2 mm intradermally into the centre of the experimental area using a hypodermic needle as guide. The temperatures were measured preburn, at the time of the burn, and then at 2, 5 and 10 min intervals for one hour in wounds 1–3 and for 1.5 h in wound 4.

This project was approved by the Ethics Committee of the University of Cape Town.

The four wounds were treated as follows:

Wound 1: received no treatment and served as a control.

Wound 2: abdominal gauze swabs were soaked in tap water at a mean temperature of 14.95°C (range 14–16°C) and placed firmly on the wound. The swabs were changed every 3 min. Continual cooling began immediately after the burn was created and continued for 1 h.

Wound 3: Melaleuca Hydrogel was applied immediately for 1 h following the burn.

Wound 4: Melaleuca Hydrogel was applied 30 min post burn and left for 1 h.

Treatment with Melaleuca Hydrogel was by single application. This consisted of opening the sealed packet and placing the foam with the gel directly onto the wound. The ambient temperature during the experiment was 23°C and the temperature of Melaleuca Hydrogel 19.5–19.6°C.

The wounds were biopsied within an hour after commencement of treatment and swabs were taken for bacteriological assessment. Thereafter all wounds were left exposed and allowed to heal spontaneously without any intervention. The wound swabs were repeated 24 h post burn and after 7, 14 and 21 days.

Core biopsies were repeated at 24 h and 3 weeks to assess the depth of each burn and measure the rate of wound healing. The biopsies were taken from standardized predetermined sites to limit histological sampling errors. The wounds were also assessed clinically by an independent surgeon after 21 days. Factors assessed were: size of wound, amount of granulation tissue, tissue infection, hair growth, eschar and the degree of wound healing and epithelialisation. The degree of wound healing was calculated clinically and from photographs taken at 21 days. In addition in each animal the 4 sites were ranked from the wound demonstrating the most healing to the wound with least healing, expressed numerically as first to fourth respectively.

3. Results

Eight pigs were available for assessment. Two pigs died in the immediate postoperative period from respiratory depression.

3.1. Cooling

Table 1 illustrates the biphasic intradermal temperature changes for the respective wounds. There was a rapid and substantial increase in intradermal temperature above the level of tissue cryo-destruction followed by dissipation of heat with a rapid reduction in temperature to below 40°C in all 3 wounds within 2 min. Thereafter intradermal temperature progressively and steadily decreased in relation to preburn temperatures over the next 58 min with a mean decrease of 7.82°C for the water cooled wound (No. 2) and 3.87°C for the immediate Melaleuca Hydrogel application wound (No. 3). Mean intradermal temperature in the non-treated wound (No. 1) was 0.4°C higher at the end of the observation period. Table 1 also depicts the temperature changes for the 30 min delay Melaleuca Hydrogel wound (No. 4). Standard deviations from all readings ranged from 1.50 to 3.75°C except for the readings at the time of the burn (0 min) which ranged from 9.12 to 12.48°C. This was due to the extremely rapid changes in temperature immediately following the creation of the burn, and clinical difficulty experienced in recording that reading at precisely the same moment in each burn wound.

Statistical analysis using a Mann–Witney U test

Table 1
Intradermal temperature profile[a]

Time (min)	Control (uncooled)	Water-cooled	Hydrogel (immediate application)	Hydrogel (30 min delay in application)
Preburn	30.68 (1.60)	31.91 (1.40)	33.76 (2.13)	33.96 (2.64)
0	67.95 (12.48)	62.63 (10.78)	69.44 (9.52)	60.23 (9.12)
2	36.63 (1.45)	34.48 (2.55)	34.67 (2.69)	38.00 (2.51)
4	33.74 (1.67)	31.07 (2.29)	33.94 (2.63)	35.68 (3.29)
6	32.91 (1.94)	29.96 (2.55)	33.49 (2.67)	34.95 (3.75)
8	32.56 (1.99)	28.29 (2.52)	33.10 (2.67)	35.01 (2.82)
10	32.30 (1.83)	27.86 (2.47)	32.79 (2.48)	34.53 (3.39)
15	32.15 (1.19)	27.26 (2.42)	31.99 (2.00)	34.20 (3.38)
20	31.75 (1.35)	26.25 (2.68)	31.04 (2.32)	33.81 (3.34)
25	31.60 (1.21)	25.85 (2.62)	30.54 (2.25)	33.80 (2.98)
30	31.49 (1.19)	25.45 (2.03)	30.15 (2.26)	33.69 (2.81)
40	31.30 (1.74)	24.39 (1.64)	29.85 (1.90)	31.00 (2.70)
50	31.14 (2.04)	24.26 (1.50)	29.85 (1.70)	31.29 (1.97)
60	31.12 (2.64)	24.09 (1.69)	29.89 (1.50)	31.25 (2.16)
				31.29 (2.13)
				31.29 (2.14)
				31.16 (2.34)
				31.09 (2.27)
				31.05 (2.30)
				31.02 (2.49)
				31.17 (2.58)
				31.50 (2.44)
				32.03 (2.49)

[a] Each temp. °C represents the mean intra-dermal temperature in 10 pigs. Figures in parenthesis represent standard deviation.

showed that there is no statistical difference between the two groups.

Control healed: $1.25 \pm 3.3\%$
Water cooled: $82.5 \pm 23\%$ (S.E.M. = 8.13)
Melaleuca Hydrogel: $64.4 \pm$(S.E.M. = 9.8)

A Mann–Whitney U test gives $U = 20$ which for an 8,8 data block shows that this is not a significant difference.

3.2. Clinical assessment

The results at 3 weeks are depicted in Tables 2–5. There was no evidence of interaction between the various lesions. Clinical assessment indicated more rapid healing in both the Melaleuca Hydrogel (immediate and delayed group) and water-cooled burns compared with the untreated controls at 3 weeks. All wounds irrespective of treatment were reduced in size by an average of 50 mm. The control wounds consistently demonstrated less than 10% healing with bleeding, scab formation, surface exudate, minimal hair growth and rated the worst on clinical assessment. In comparison, all the cooled wounds showed various degrees of healing with minimal scab formation, hair growth and re-epithelialisation. The degree of wound healing ratings were consistently above the control wound. Overall the water cooled wounds demonstrated the most marked healing and immediate or delayed Melaleuca

Table 2
Wound characteristics at 3 weeks. Wound 1: control

	Animal number							
	1	2	3	4	5	6	7	8
Size (mm)	80 × 60	70 × 50	65 × 78	75 × 75	80 × 80	70 × 70	55 × 55	75 × 50
Scab	loose	minimal	thick	thick	thick	thick	loose	loose
Bleeding	nil	nil	nil	nil	nil	nil	nil	nil
Infection	nil	nil	nil	nil	nil	nil	nil	nil
Hair growth	present	sparse	nil	nil	sparse	nil	nil	sparse
% Healed	0	10	0	0	0	0	0	0
% Healing	0	0	0	0	0	0	0	0
Rating of healing	4th	4th	4th	4th	4th	4th	4th	4th

Table 3
Wound characteristics at 3 weeks. Wound 2: water cooled

	Animal number							
	1	2	3	4	5	6	7	8
Size (mm)	87 × 68	75 × 60	70 × 70	70 × 80	90 × 75	75 × 0	90 × 85	90 × 80
Scab	loose	minimal	minimal	minimal	thick	thick	serous	thick
Bleeding	nil	nil	nil	nil	nil	nil	nil	nil
Infection	nil	nil	nil	nil	nil	nil	nil	nil
Hair growth	present	present	present	present	minimal	present	present	present
% Healed	100	90	50	80	100	40	100	100
% Healing	0	10	50	20	0	60	0	0
Rating of healing	1st	2nd	2nd	1st	3rd	2nd	1st	1st

Table 4
Wound characteristics at 3 weeks. Wound 3: immediate "Melaleuca Hydrogel"

	Animal number							
	1	2	3	4	5	6	7	8
Size (mm)	73 × 62	65 × 60	60 × 60	70 × 70	80 × 70	80 × 80	90 × 85	65 × 60
Scab	loose	minimal	minimal	minimal	thick	adherent	serous	nil
Bleeding	nil	nil	nil	nil	nil	nil	nil	nil
Infection	nil	nil	nil	nil	nil	nil	nil	nil
Hair growth	nil	nil	present	present	present	present	present	nil
% Healed	80	20	50	30	100	60	100	75
% Healing	20	50	50	70	0	40	0	25
Rating of healing	3rd	3rd	1st	3rd	2nd	1st	1st	3rd

Hydrogel treatment showed no demonstrable difference.

3.3. Histology

Histological samples taken 1 h post burn showed deep partial thickness (3) and near full thickness (5) dermal burns in the control wound. In the water-cooled wounds (1 full thickness and 7 partial thickness injuries), tissue destruction was less marked with coagulative necrosis of the surface epidermis and superficial portion of the dermal appendages. Deep dermal structures and all fibroadipose tissue were viable. Immediate and delayed Melaleuca Hydrogel wounds were all partial thickness, except for 2 full thickness wounds in the delayed group. Similar histological findings were observed at 24 h post burn. These histological changes reflect the influence of cryotherapy on thermally induced tissue destruction.

After 21 days all the cooled wounds showed almost complete healing. There was no histological difference between the water cooled and Melaleuca Hydrogel cooled wounds. In the control wound, healing was noted to be poor. Seven out of 8 of the wounds were

Table 5
Wound characteristics at 3 weeks. Wound 4: delayed Melaleuca Hydrogel

	Animal number							
	1	2	3	4	5	6	7	8
Size (mm)	75 × 55	60 × 45	70 × 65	50 × 80	85 × 70	65 × 70	75 × 83	85 × 60
Scab	minimal	minimal	minimal	minimal	thick	loose	serous	adherent
Bleeding	nil	nil	nil	nil	nil	nil	nil	nil
Infection	nil	nil	nil	nil	nil	nil	nil	nil
Hair growth	present	present	present	present	present	present	present	present
% Healed	90	80	50	80	100	10	100	80
% Healing	10	20	50	20	0	90	0	20
Rating of healing	2nd	1st	3rd	2nd	1st	3rd	1st	2nd

covered by slough and granulation tissue and partial to no re-epithelialisation had occurred in 6/8 wounds. Viable adnexal structures were also absent in 5 wounds.

3.4. Bacteriology

Immediately post burn the control and Melaleuca Hydrogel treated wounds were sterile. A few Staphylococcus epidermidis organisms were isolated from the surface of the water cooled group.

There was no difference seen in the number of bacteria isolated from the different wounds on days 7, 14 and 21. All surfaces were heavily contaminated with predominantly enteric bacilli, scanty *Staphylococcus epidermidis* and *Staphylococcus saprophyticus*. No overt infection in any of the wounds were noted.

4. Discussion

Cooling the burn wound as an emergency measure has been shown to be beneficial both clinically and experimentally [10–16]. Cryotherapy improves the tissue response to thermal injury. This is achieved by a reduction in post burn hyperthermia, reduced inflammatory and microvascular changes, and less tissue necrosis and fibrosis. In addition there is less release of histamine, prostaglandins, thromboxanes, as well as reduced aerobic metabolism, less lactate production and metabolic acidosis. An increase in epithelial cell growth [1,4,5,7,17–19] has also been noted. Immersion into cold water also significantly reduces pain and discomfort and reduced the mortality of experimental full thickness burn from 64.5 to 2.58% [12,13].

The optimum temperature at which to achieve maximum benefit remains undetermined. Experiments have been conducted with temperatures ranging between −6 and +12.6°C (Pushkar 15°C, King 10–12°C, Boykin 8–10°C, Raghupati 17°C, Demling 15°C, Orfeigsson 15–30°C, Davies 25–30°C) [6,16,18,21,10,14,1]. These temperatures refer to the surface temperatures of the coolant and the effect on intradermal temperatures are not recorded. However, cold water compresses at 1–8°C were shown to confer no benefit to burned skin as the corresponding intradermal temperatures of between 13.5°C and 15.5°C cause extensive cryodestruction leading to more tissue damage and delayed healing in comparison to wounds not cooled or cooled with water temperature between 12 and 15°C [20]. Thus in the conducted experiment we chose cold tap water at approximately 15°C as the most practical and useful cryotherapy agent to compare with Melaleuca Hydrogel [21,22].

Our study clearly demonstrated the beneficial effects of cooling the partial thickness burned wound for at least 1 h by means of either repeated cold tap water compresses at ±15°C or with Melaleuca Hydrogel. The treated wounds consistently demonstrated more advanced healing. At 21 days almost complete epithelisation was evident in most wounds; only 25% of the water cooled and 36% of Melaleuca Hydrogel wounds did not show more than 75% re-epithelisation. Even with a 30 min time delay before initiating cooling, the wounds both clinically and histologically showed limited damage and advanced healing. These findings have obvious clinical implications. However, due to the dynamic and progressive nature of local tissue destruction, therapy must be instituted as soon as possible to be of any value [23].

Melaleuca Hydrogel is readily available as a compact, easily transportable light dressing, available in different sizes. A single application of Melaleuca Hydrogel is as effective as repeated cold water compresses and it is unlikely that Melaleuca Hydrogel application could lead to significant hypothermia when applied on a large burn. However, exposed Melaleuca Hydrogel showed signs of drying out after one hour and an additional application may be required if cooling is to be continued for an extended period.

The mechanism of action of melaleuca is unknown but may be partly due to caloric exchange, as the gel is 96% water by volume. Although pigskin is anatomically similar to human skin caution must be exercised in interpreting these results in relation to human thermal injury. Further clinical studies are required to confirm the efficiency of Melaleuca Hydrogel as an emergency topical antithermal agent.

The temperature of the cooled wound and the rate of cooling of burned tissue are of major importance in determining the effect of cooling. Water compresses and Melaleuca Hydrogel reduced elevated intradermal temperatures to below preburn levels within 6 min of application. This reduction in temperature was also well above the temperature of cryodestruction and without the potential risk of hypothermia and the reduced blood flow inherent in ice or very cold water methods [11,16,24]. This cooling effect was maintained for at least a further 58 min – the end of the observation period – thereby presumably minimising the effects of heat on the tissues and so enhancing the healing process [6,18,19,24]. Cryotherapy can also reduce the formation of microabscesses in a burn wound.

This study attests to the benefits of cooling the burn wound. Tap water (at 16–18°C) is readily available, and when applied as repeated cold water compresses reduced intradermal temperature and led to increased wound healing. However, the process does need to be repeated frequently. Melaleuca Hydrogel, which is 90% water by composition was also effective in reducing the intradermal temperature and increasing wound healing in the porcine model. It is more expensive and not as readily available as cold water compresses, but can be applied less frequently.

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