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Optimal Duration of Cooling for an Acute Scald Contact Burn Injury in a Porcine Model

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The Australian and New Zealand Burn Association recommend 20 minutes of cold running tap water as burn first aid. Scientific evidence for the optimal duration of treatment is limited. Our aim was to establish the optimal duration of cooling using cold running tap water to treat the acute burn. Partial thickness contact scald burns were induced at five sites in each of 17 pigs. Treatments with cold running tap water for 5, 10, 20, and 30 minutes were randomly allocated to different sites together with an untreated control site. In the running water 5 and 10 minute treatments intradermal temperatures rose by 1°C per minute when cooling was stopped, compared with 0.5°C per minute for 20 and 30 minutes duration. No differences in the surface area of each burn were noted between the five treatments on day 9. Histological analysis of burn depth on days 1 and 9 revealed that a higher proportion of burns treated for 20 and 30 minutes showed improvement compared with those treated for 5 and 10 minutes only. This difference reached statistical significance ($P < .05$) only in the cold running water for 20 minutes treatment arm. There was a statistically significant ($P < .05$) improvement in burn depth in a porcine acute scald burn injury model when the burn was treated with cold running tap water for 20 minutes as opposed to the other treatment durations. This study supports the current burn first aid treatment recommendations for the optimal duration of cooling an acute scald burn. (J Burn Care Res 2008;29:828–834)

The current recommendation for immediate management of an acute burn injury is 20 minutes of cool running tap water.[1] Cooling not only limits the depth of the burn but also has a profound analgesic effect.[2,3] Cool running tap water, as opposed to wet towels, a fine water spray or no treatment, has been shown to be the most effective modality for treating an acute scald burn in a porcine model.[4] This model was selected on the basis of the similarity between porcine and human skin.[5–7]

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Clinical data would suggest that, even when cold running water (RW) is used for burn first-aid treatment (BFAT), patients often receive this for <20 minutes.[8,9]

Failure of adherence to the recommended guidelines may in part reflect the lack of compelling scientific evidence for the optimal duration of cooling.[9,10]

Our aim was to establish the optimal duration of cooling using cold running tap water by treating an acute contact scald burn in a porcine model for 5, 10, 20, and 30 minutes, and comparing the outcomes of each treatment with a control burn which received no treatment.

METHODS

Animal Model

The experimental model was adapted from Jandera et al, which was based on a histopathological study of scalds and contact burns in a porcine model.[5,11] Seventeen large white piglets were used with a mean weight of 12 kg (range 10–15). Five identical circular scald

burns were induced and evenly spaced on each pig, three on one flank and two on the other.[4] The mean TBSA of the burn in each pig was 2%.[12] The study was approved by the Ethics Committee of our institution.

General Anesthesia and Monitoring

Intramuscular injection of a mixture of atropine (0.04 mg/kg), zolazepam/tiletamine (Zolatil®, Vibrac, NSW, Australia; 4.4 mg/kg), xylazine (2.2 mg/kg), and azaperone (2.2 mg/kg) was administered to each animal. Isoflurane gas was used for maintenance during experimentation. Buprenorphine hydrochloride (0.01 mg/kg) analgesia was given before reversing general anesthesia. For the duration of experimentation, heart rate, respiratory rate, mucus membrane color, and rectal temperatures were recorded every 3 to 5 minutes. The body temperature of the animal was maintained with a warming mattress throughout the study.

Wound Preparation

Under general anesthesia, dorsal flank skin was shaved, washed and dried. Circular areas for burn induction were outlined with a marking pen. Povidone iodine (Betadine®) was used to prepare the area for intradermal insertion of a cannula (12FG × 9 cm dwellcath®). A temperature probe was then fed through the cannula under aseptic conditions. The point of entry was located just outside each scald region and the needle advanced obliquely, with the tip positioned in the center of the circular scald area intradermally. This method was used to minimize the possibility of heat transfer along the probe. For the duration of the treatment for each site, intradermal temperatures were recorded continuously. Fluke® (Evertt, WA, Australia) wire thermometers enabled continuous digital monitoring of temperature changes.

Scald Induction

The contact scald burn injury was induced by application of a purpose-made bottomless mug, made of Delrin® (DuPont), sealed at the base with Tegaderm® (3M Health Care Ltd., St. Paul, MN).[11] The mug was filled with 300 ml of water at mean temperatures of 87.5°C (84.0–91.0). The base was then applied to the marked region which had been slightly moistened to ensure optimal thermal coupling. To reduce variability, the burn was always induced by the burns fellow (N.B. and J.Y.). Contact was maintained for 15 seconds, consistently producing a partial thickness burn.

Treatment

Each burn was then cooled with running tap water (mean temperature 22.4°C) for either 5, 10, 20, or 30 minutes. A control site received no treatment. Treatments were randomly allocated to each burn site to exclude any bias as a result of variation in the thickness of the skin at different sites on the animal's flank.

Once first aid was complete, each burn site was cleaned and dressed with Bactigras® (Smith and Nephew, Hull, UK; chlorhexidine and paraffin impregnated gauze), secured with Hypafix® (Smith and Nephew) and a body sock.

Assessment

The outcome measures collected included the intradermal temperatures, recorded continuously during procedure; surface areas of the burn measured in cm^2 on days 1 and 9, and skin biopsy for histological assessment of burn depth taken on days 1 and 9 postburn.

Intradermal temperature at each burn site was recorded at −2, −1, 0 (time of burn induction) and subsequently at 1 minute intervals for a minimum of 30 minutes postburn at each site. To avoid hypothermia and adverse consequences because of the overall length of the experiment, intradermal temperatures were monitored for between 5 (30 minutes cold RW) and 30 (5 minutes cold RW) minutes after completion of treatment. Burn surface area was measured by tracing each burn with a transparency and subsequently measuring the surface area of each burn in square centimeter. Skin biopsies were taken from an area which macroscopically represented the deepest part of the burn using a 4-mm punch biopsy. This was fixed in formalin and prepared for staining with Hematoxylin and Eosin, periodic acid-Schiff, and Masson's Trichrome. Each biopsy was then analyzed for burn depth by a senior pathologist who was blinded to the various treatments applied to each burn. Burn depth analysis by histological assessment was rated on a scale from 1 to 6 (Table 1). Histological evaluation was judged according to the level of thrombosis of blood vessels, vascular wall damage, extravasation of erythrocytes, infiltration by

Table 1. Burn depth assessment

Rating Scale	Description
1	Healed/normal
2	Epidermal damage
3	Superficial dermal damage
4	Mid-dermal damage
5	Deep dermal damage
6	Deep/full thickness

inflammatory cells, destruction of dermal appendages, evidence of necrosis, regeneration, acanthosis, and destruction of the basement membrane.

Data Analysis

Statistical Package for Social Sciences for Windows, version 13.0 (SPSS Inc., Chicago, IL) and Microsoft excel XP were used to perform paired *t* tests to compare means or McNemar's χ^2 analysis for matched pairs using confidence intervals of 95%. $P < .05$ was considered statistically significant.

RESULTS

Intradermal Temperatures

The peak temperatures reached was not significantly different between the treatment and control groups ($P > .05$, McNemar's test). In the RW 5 and 10 minute treatments intradermal temperatures rose by 1°C per minute when cooling was stopped. Intradermal temperatures rose more gradually, by 0.5°C per minute from cessation of cooling, in the RW 20 and 30 minute treatments although this difference was not statistically significant (Figure 1).

Core Temperatures

The mean core body temperature did not fall below 34°C throughout the cooling process. Recovery in all 17 pigs was uneventful.

Mean Surface Area of Burns at Day 1 and 9

The mean surface areas of all burns decreased because of wound healing between day 1 (mean area 0.0023 m^2) and day 9 (mean area 0.0013 m^2) in all treatments including the control burn. There was no statistically significant difference noted in the surface area of the burns comparing the five treatments on day 9 ($P > .05$, McNemar's test). The duration of cooling a burn thus did not impact on the surface area of the burn at the end of the healing process (Figure 2).

Histological Comparison of Burn Depth

Histological assessment of burn depth from biopsies taken on day 1 showed no significant difference in burn depth rating in the five treatments ($P > .05$, McNemar's test). The mean burn depth rating was 3.2 ($\pm$SD = 0.3) in all treatments. This indicated that the method of burn induction was consistent in all of the five treatments as found in our earlier study of BFAT using the same model.[4]

The majority of burns in the control, RW 5 and 10 minute treatments showed no change during the 9 day period. In marked contrast, a greater number of burns which revealed improvement were treated with RW for 20 and 30 minutes (Figure 3). On day 9, the mean burn depth rating remained at 3.2 ($\pm$SD = 0.7) in the control, RW 5 and 10 treatments. In RW 20 minute treatment, the mean burn depth rating improved to 2.7 ($\pm$SD = 0.8) and in the 30 minute treatment to 2.9 ($\pm$SD = 0.9). A statistically significant difference in burn depth rating was noted in the RW 20 minute treatment ($P < .05$, McNemar's test, Figures 4 to 8).

DISCUSSION

Australian and New Zealand Burn Association guidelines and teaching on the association Emergency Management of Severe Burns course has advocated

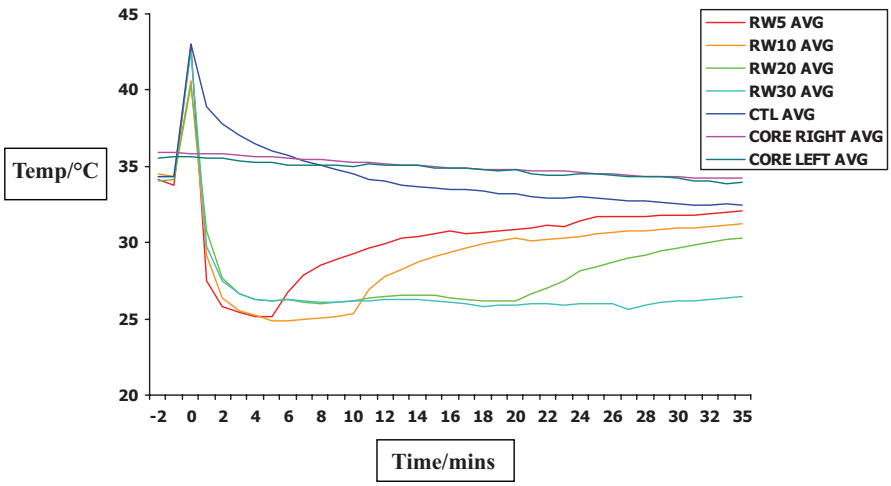

Figure 1. Mean intradermal temperatures more than 30 minutes for each treatment.

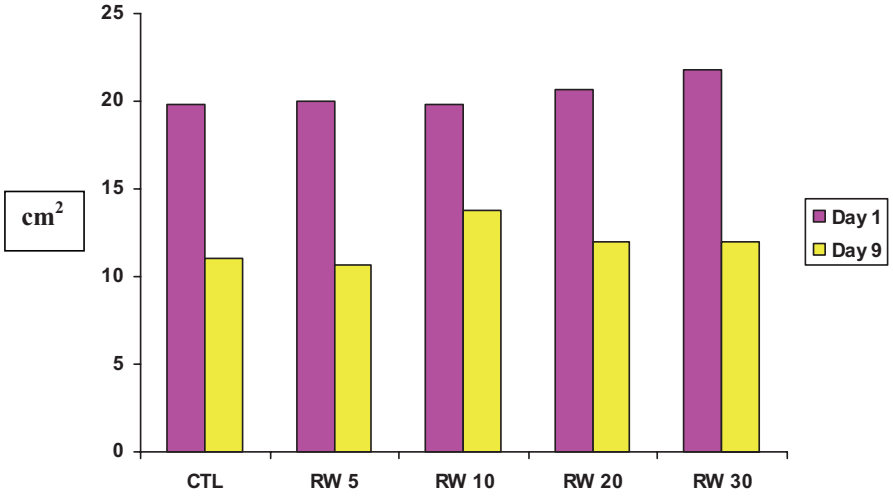

Figure 2. Mean area of burn (cm^2) at days 1 and 9.

cold RW for at least 20 minutes as optimal BFAT.[1] In clinical practice, factors such as the circumstances of the burn injury, the level of analgesia that cold water lends to the burn, patient compliance, the anatomical location of the burn, and the risk of inducing hypothermia (in larger body surface area burns) are often what determine the duration of cooling.

The use of cold water as first aid for a burn is by no means new. Such therapy was recommended by Galen (AD 129–199), Rhazes (AD 852–923), Earle (1799), and Sorensen (1967).[13] The scientific evidence, however, for the use of cold, running tap water over other common modes of application of water has only recently been demonstrated.[4] Several studies have suggested that for optimal clinical benefit, cold running tap water should be between 12 and 27°C.[14–16] Iced water or water cooler than 8°C seems detrimental for survival and burn wound healing in the majority of studies and in practice would rarely be immediately available for BFAT.[13,17–19]

The question of how long to cool a burn, however, to limit its depth has been largely unanswered. Data supporting the optimal duration of BFAT have remained limited, with recommendations in the literature ranging from 5 to 45 minutes.[20–22] Many of these recommendations for duration of cooling of an acute burn were found to be largely anecdotal.[13,19,23,24] This may have contributed to confusion of information available relating to the duration of optimal BFAT on the internet, with recommendations varying from "several minutes," "5 minutes,"

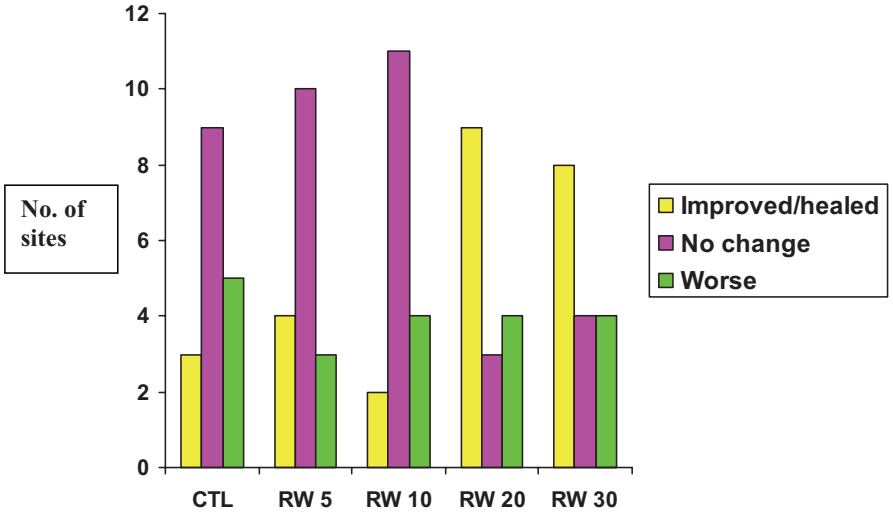

Figure 3. Histological assessment of burn wound healing during the course of 9 days.

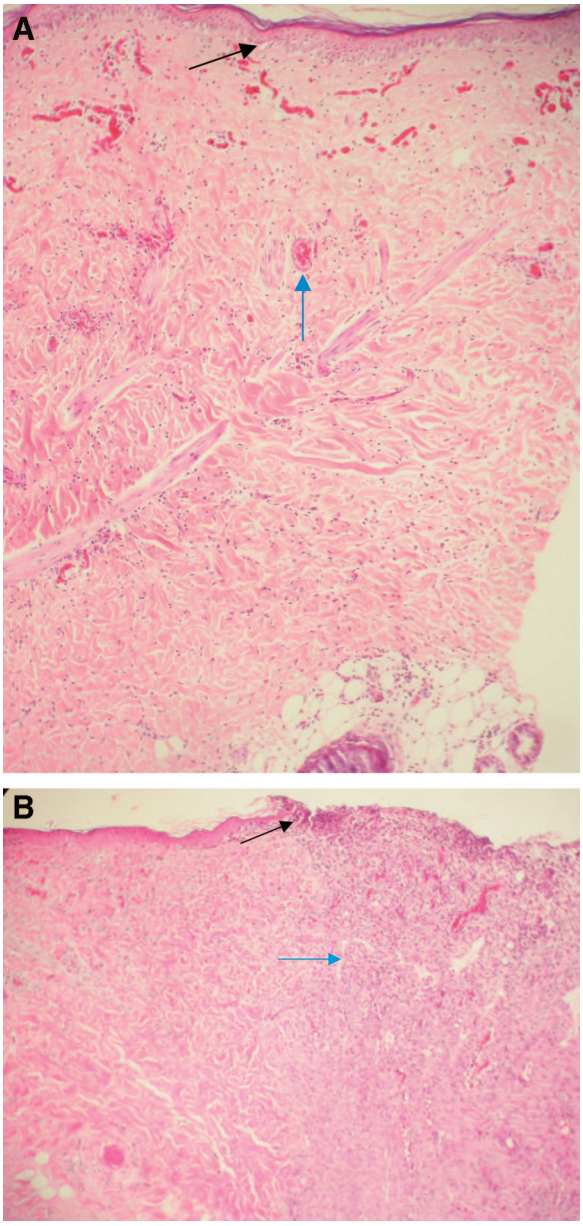

Figure 4. A. Control burn site of animal O at day 1 (Hematoxylin and eosin; ×10). Shows vacuolization of basal epidermal cells (black arrow). Vessels are congested with focal red blood cell extravasation (blue arrow). B. Control burn site of animal O at day 9 (Hematoxylin and eosin; ×10). Shows epidermal necrosis and ulceration (black arrow), with fibrosis of the dermis (blue arrow).

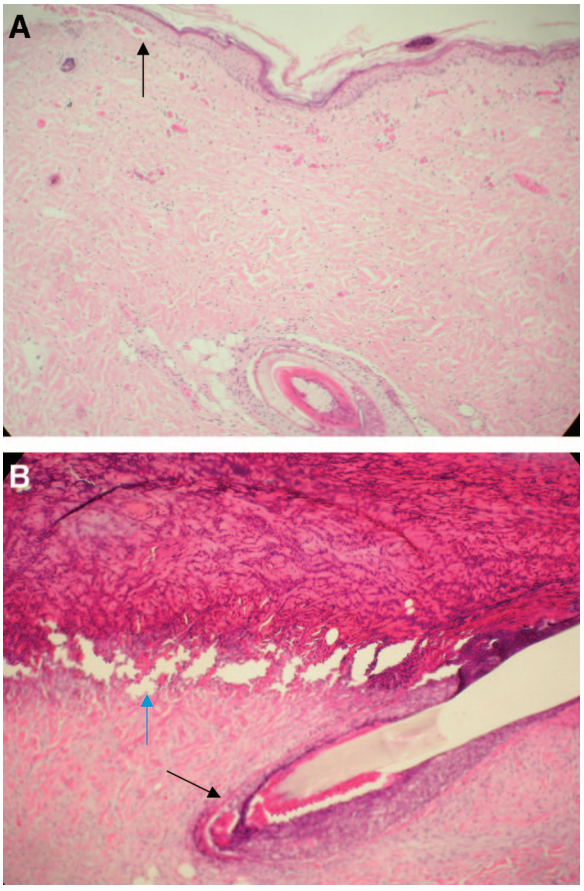

Figure 5. A. Cold running water treated burn for 5 minutes of animal J at day 1 (Hematoxylin and eosin; ×10). Shows basal vacuolization and lifting of epidermis from basement membrane (black arrow). B. Cold running water treated burn for 5 minutes of animal J at day 9 (Hematoxylin and eosin; ×10). Necrosis of hair follicle (black arrow) with ulceration of the epidermis (blue arrow).

"10 minutes," "until the pain subsides," or "until an ambulance arrives."[25–28]

This study found that 20 minutes seems to be the optimal duration of cooling using cold running tap water for an acute contact scald burn wound in a porcine model. Cooling for shorter time periods of 5 and 10 minutes did not improve burn depth but might have provided an analgesic effect in vivo. Cooling for 30 minutes, on the other hand, did not show a statistically significant improvement in burn depth rating. One explanation for the latter could be that at this stage of the experiment the average core body temperature of the pigs measured 34°C. This factor alone would have contributed to hypoperfusion of the dermis and lack of significant improvement in burn depth.[29]

The 5 and 10 minute time points were chosen on the basis of our observations of what generally occurs after a burn in the home environment.[9] Similarly, the 20 and 30 minute time points were chosen as they represent frequently quoted durations of cooling for an acute burn wound.[1,8,9,28,30] Cooling the burn for any greater length of time would

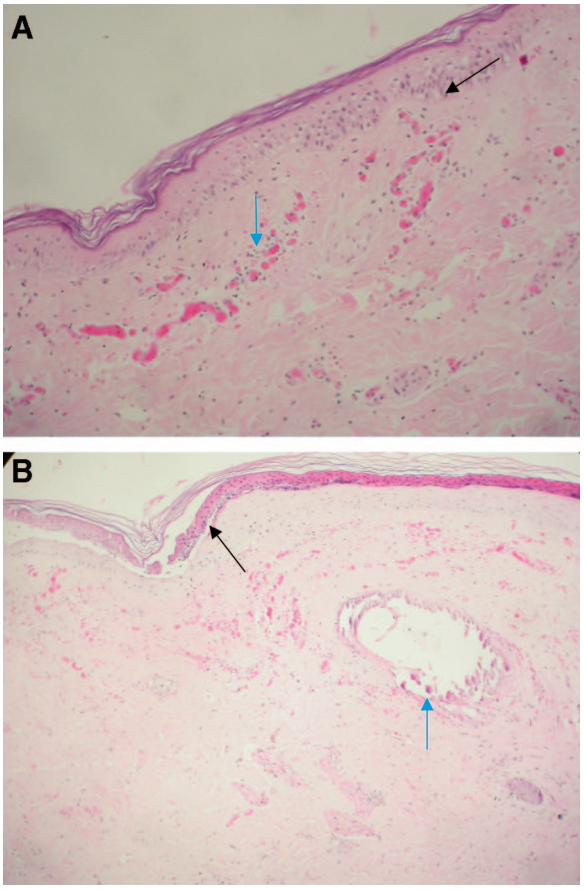

Figure 6. A. Cold running water treated burn for 10 minutes of animal N at day 1 (Hematoxylin and eosin; ×10). Shows vacuolization of basal epidermal cells (black arrow), with congestion of vessels and extravasation of red blood cells (blue arrow). B. Cold running water treated burn for 10 minutes of animal N at day 9 (Hematoxylin and eosin; ×10). Shows necrosis and lifting of the epidermis from the basement membrane (black arrow), with necrosis of a hair follicle in dermis (blue arrow).

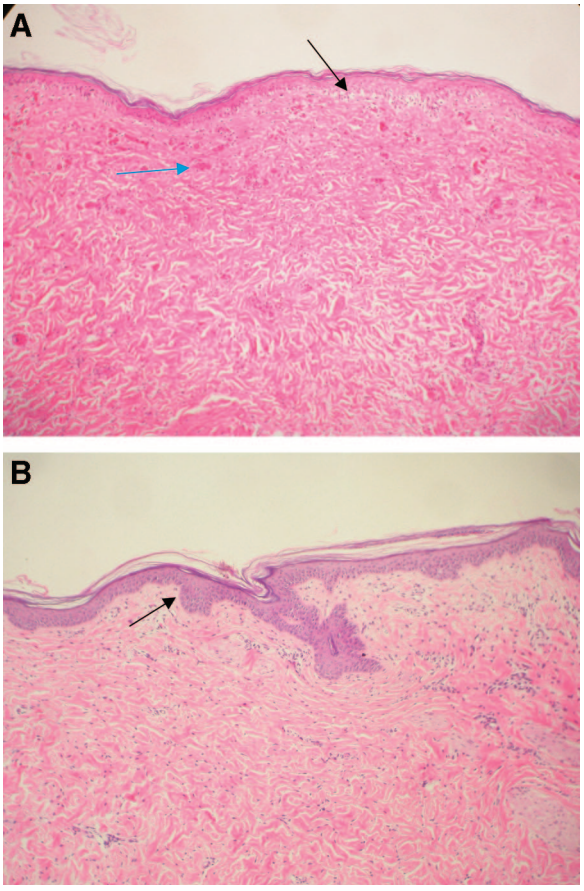

Figure 7. A. Cold running water treated burn for 20 minutes of animal E at day 1 (Hematoxylin and eosin; ×10). Shows vacuolization of basal epidermal cells (black arrow), with vascular congestion, focal extravasation of red blood cells and a minor inflammatory response (blue arrow). B. Cold running water treated burn for 20 minutes of animal E at day 9 (Hematoxylin and eosin; ×10). Shows regeneration of epidermis with mitotic activity (black arrow).

have lead to an increased risk of hypothermia, thereby jeopardizing the overall condition of the animals. No adverse outcome was noted in any of the 17 pigs used in this experiment although each experiment lasted for approximately 2.5 hours. In the clinical situation cooling a burn for longer than 20 minutes, especially when a larger TBSA may be involved, presents a significant risk of hypothermia, particularly in the pediatric population.[1,9]

One of the most important outcome measures that have clinical implications remains burn depth. In our study this was assessed histologically using standard staining methods.[31,32] The same pathologist, who was blinded to the burn treatments, analyzed all 170 biopsies, thereby optimizing the accuracy of the data that our study lends to burns first aid.

Most international burns associations currently endorse the use of cold water for emergency management of the burn for 20 to 30 minutes. Our study provides scientific evidence to support immediate cooling of an acute scald burn injury for 20 minutes. This will minimize burn depth, which in turn will facilitate spontaneous healing.

Having provided scientific evidence for optimal burns first aid we intend to continue educating the public regarding the same to minimize the impact that a burn and it's treatment has on a child and it's family.[33]

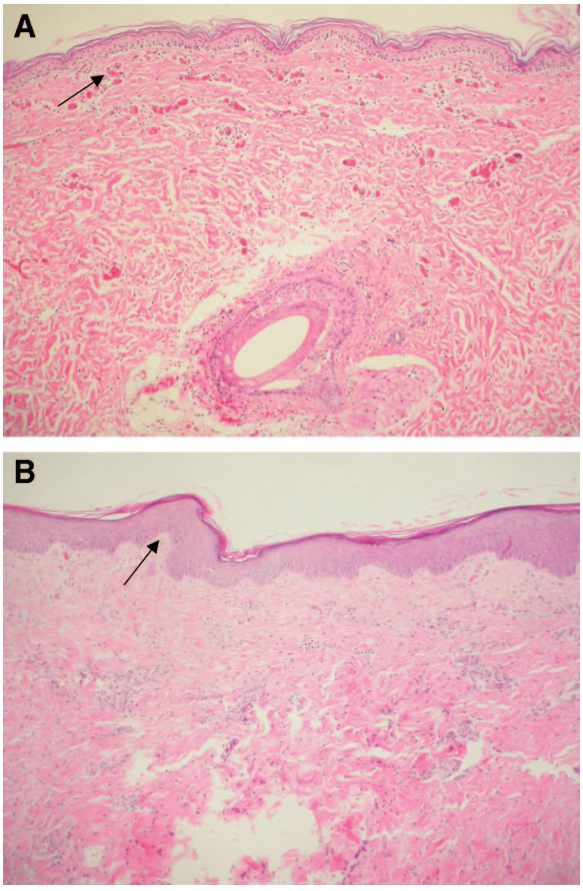

Figure 8. A. Cold running water treated burn for 30 minutes of animal S at day 1 (Hematoxylin and eosin; ×10). Shows vacuolization of basal epidermal cells vascular congestion, extravasation of red blood cells (black arrow) and minor inflammatory response. B. Cold running water treated burn for 30 minutes of animal S at day 9 (Hematoxylin and eosin; ×10). Shows regenerative hyperplasia of the epidermis (black arrow).

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