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Microvascular blood flow in scalds in children and its relation to duration of wound healing: A study using laser speckle contrast imaging

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ABSTRACT

Background: Microvascular perfusion changes in scalds in children during the first weeks after injury is related to the outcome of healing, and measurements of perfusion, based on laser Doppler imaging, have been used successfully to predict the need for excision and grafting. However, the day-to-day changes in perfusion during the first weeks after injury have not to our knowledge been studied in detail. The aim of this study, based on a conservative treatment model where excision and grafting decisions were delayed to day 14 after injury, was to measure changes in perfusion in scalds using laser speckle contrast imaging (LSCI) during the first three weeks after injury.
Methods: We measured perfusion with LSCI in 34 patients at regular intervals between 6 h after injury until complete reepithelialization or surgery. Duration of healing was defined as the time to complete reepithelialization.
Results: Less perfusion, between 6 and 96 h after injury, was associated with longer duration of healing with the strongest association occurring between 72 and 96 h. Burns that healed within 14 days had relatively high initial perfusion, followed by a peak and subsequent slow decrease. Both the maximum perfusion and the time-to-peak were dependent on the severity of the burn. Burns that needed excision and grafting had less initial perfusion and a gradual reduction over time.
Conclusion: The perfusion in scalds in children shows characteristic patterns during the first weeks after injury depending on the duration of wound healing, the greatest difference between wounds of different severity being on the 4th day. Perfusion should therefore preferably be measured on the fourth day if it is to be used in the assessment of burn depth.

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Abbreviations: LDI, laser Doppler imaging; LSCI, laser speckle contrast imaging; PU, perfusion units; ROI, region of interest.
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1. Introduction

The most common way to assess the depth of a burn is by looking at the wound and making a subjective assessment of capillary refill. Even though this method is immediate, easy and cost-effective [1], inaccurate prognoses are made in about a quarter of cases [2]. There is therefore a need for more reliable techniques for early prediction of the depth of a burn. The perfusion of blood in a superficial scald is typically higher than the perfusion of the surrounding uninjured skin, while a deeper scald often has a degree of perfusion similar to, or less than that of uninjured skin [3,4]. The perfusion of a scald has therefore been used as a diagnostic marker during assessment of the depth, which is of particular interest in intermediate burns as they are difficult for even experienced surgeons to diagnose correctly at initial presentation [5].

Several ways have been developed during recent years to measure perfusion objectively for the assessment of the depth of a burn and its healing potential, and these include near infrared spectroscopy, laser Doppler flowmetry (LDF), and laser Doppler imaging (LDI) [6]. Of those, only LDI is currently used clinically as a tool for the assessment of burns.

One of the major drawbacks of LDI is the time required to complete a scan of any larger area of skin, which is typically several minutes. As well as the practical disadvantage of the measurement taking a long time, LDI also tends to be affected by motion artefacts leading to inaccurate measurements, particularly in children [7]. Laser speckle contrast imaging (LSCI) is a recently developed technique that, like LDI, is able to measure perfusion in an area of skin, but within less time – typically a fraction of a second to a few seconds, depending on the image acquisition parameters, while at the same time maintaining high spatial resolution. These properties make LSCI a promising technique for the assessment of burns.

We have previously shown [3] that perfusion measured with LSCI is higher in scalds that heal within 14 days than in wounds that undergo more than 14 days for reepithelialization, and this difference is already evident within the first 24 h after injury.

In this study, in which we have included more scalds of various depths, we hypothesized that burns of differing severity and with different outcomes show evidence of specific perfusion dynamics during the first weeks after injury. Our aim was therefore to investigate how the perfusion in scalds in children (as measured by LSCI) changes during the first 15 days after the injury, and how this relates to the severity of the wound expressed as the time for the wound to heal fully.

2. Patients and methods

We invited all children with scalds who were admitted to the intensive burn care unit at Linköping University Hospital, or who were treated as outpatients, to participate in the study, and a total of 34 patients (14 of whom were female) were included. Their mean age was 2.7 (range 0.8–14.1) years. All patients initially received conservative treatment and a formal surgery decision was not made until 14 days after injury. Surgery was done when the treating physician predicted a wound area would take around 21 days after injury or more to heal. As all the children were under the age of consent, their parents or guardians gave permission for their participation in the study. The study was done in accordance with the Helsinki Declaration. The regional ethics committee approved the study on 22 February 2012, DNr 2012/31/31.

2.1. *Equipment*

We used a laser speckle contrast imager (Pericam PSI, Perimed AB, Järfälla, Sweden) to measure skin perfusion. The system uses a divergent laser beam with a wavelength of 785 nm to illuminate the skin, and creates a speckle pattern over the area that is illuminated. It uses two cameras, one that captures the speckle contrast image and the other that captures a conventional color image of the measured area. The principle of the technique of LSCI has been previously described in detail [3]. We set the image size to correspond to a 12 cm $\times$ 12 cm area of skin, kept the distance between the camera and the skin to between 18 and 27 cm, and set the acquisition rate to 21 images/second. With each measurement, the system calculated the mean perfusion from 42 consecutive images, which resulted in a measurement time of 2 s for each scan. The spatial resolution of the perfusion image was 0.2 mm/pixel. The LSCI system was calibrated at regular intervals as recommended by the manufacturer. In 11 ROI in two patients, 5 subsequent scans were captured within a period of 1 min to assess the reproducibility of the technique.

2.2. *Measurement of perfusion*

All patients received sedatives during redressing of the wound in accordance with normal clinical practice. Usually this was a combination of midazolam and ketamine, with an addition of nitrous oxide occasionally. Propofol was however used in cases with more extensive scalds or when the patient reported side-effects from the ketamine. In a few cases, mostly older patients, satisfactory effect was achieved by nitrous oxide alone. We always measured the perfusion in the wound during the first visit directly after debridement and cleaning of the wound with sterile saline, which was between 6 and 72 h after the injury. In most patients we then made additional measurements each time that the wound was dressed, typically every 2–4 days depending on the extent of the injury. Whenever possible we acquired images from the same areas of skin during subsequent visits so that we could follow changes in perfusion in the same wound over time. Some wounds were covered by biological dressings or xenografts (pigskin), and those were not always removed when the wound was dressed. As we have previously seen that the presence of these dressings has a large effect on the measurement of perfusion, we excluded those regions from the analysis. We also excluded injuries on the hands, feet, and cheeks, because we think that they could confound the data as a result of a relatively high and more variable baseline perfusion. In each image, we outlined regions of interest (ROI) using the LSCI software (PIMSoft 1.3, Perimed AB, Järfalla, Sweden). We often acquired several images from the same patient, and each image could have multiple ROI in case there