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Accuracy of laser speckle contrast imaging in the assessment of pediatric scald wounds

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ABSTRACT

Background: Changes in microvascular perfusion in scalds in children during the first four days, measured with laser speckle contrast imaging (LSCI), are related to the time to healing and need for surgical intervention. The aim of this study was to determine the accuracy (sensitivity and specificity) of LSCI on different days after injury in the prediction of healing outcome and if the accuracy can be improved by combining an early and a late measurement. Also, the accuracy of LSCI was compared with that of clinical assessment.

Methods: Perfusion was measured between 0-24 h and between 72–96 h using LSCI in 45 children with scalds. On the same occasions, burn surgeons assessed the burns as healing <14 days or healing >14 days/surgery. Receiver operating characteristic (ROC) curves were constructed for the early and late measurement and for the double measurement (DM) using two different methods.

Results: Sensitivity and specificity were 92.3% (95% CI: 64.0–99.8%) and 78.3% (95% CI: 69.9–85.3%) between 0-24 h, 100% (95% CI: 84.6–100%) and 90.4% (95% CI: 83.8–94.9%) between 72–96 h, and was 100% (95% CI: 59.0–100%) and 100% (95% CI: 95.1–100%) when combining the two measurements into a modified perfusion trend. Clinical assessment had an accuracy of 67%, Cohen's κ=0.23.

Conclusion: The perfusion in scalds between 72–96 h after injury, as measured using LSCI, is highly predictive of healing outcome in scalds when measured. The predictive value can be further improved by incorporating an early perfusion measurement within 24 h after injury.

1. Introduction

Assessment of partial-thickness burns is a difficult task even for the experienced burn surgeon, and the accuracy of assessment of burn depth varies between 60% and 75% [1]. Burn depth is usually assessed by investigating capillary refill time, sensibility and the appearance of the wound [2,3]. These factors are all evaluated in a subjective way, often without the use of an established protocol. The accuracy therefore ultimately depends on the accumulated experience of the burn surgeon, and delays in surgical decisions are common.

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This may have implications for the patients, as it is known that early surgical treatment of deep dermal burns has a better clinical outcome with reduced prevalence of hypertrophic scarring [4,5]. Early, accurate assessment of the burn is thus important for the patient because it allows for early intervention, if needed.

Many burns become deeper over time in a process called burn wound conversion [6–8]. The underlying mechanisms are not completely known, but local effects on the microcirculation with vasodilation, vasoconstriction and microthrombosis have been suggested to be of importance [6,7]. Burn wound conversion is reported to occur early, often within the first 48 h after injury [7,8]. Changes in microvascular measures that occur within a three-day time frame after injury, may therefore have high predictive value for the outcome of the wound.

Objective measurement of perfusion has been shown to be a reliable predictor of the healing capacity of the wound [9]. Laser Doppler Imaging (LDI) is currently the leading non-invasive method of measuring tissue perfusion in burns [10]. A study investigating the accuracy of clinical assessment by senior surgeons compared to LDI showed that the accuracy of the surgeons varied between 40.6% and 61.5% while LDI-assistance resulted in an accuracy of 54–95% during the first 0–3 days after injury [11]. On day 5, clinical assessment had 71.4% accuracy while LDI had 97% accuracy [11]. At 8 days after injury, however, both methods achieved 100% accuracy indicating that the strength of the LDI technique lies in early predictions of burns [11]. The fact that LDI is so successful in early prediction of the wound outcome highlights the value of perfusion measurements for early assessment of burns as shown in several studies [11–21].

Despite the fact that LDI has been extensively validated, the technique has gained limited clinical use. This may be partly due to its cumbersomeness, long measurement time (a typical LDI scan takes 1–5 min to acquire and several scans may be needed) or issues related to motion artifacts. The risk for motion artifacts is particularly relevant in children. Some previous studies on LDI have therefore been confined to adults or adolescent patients [14,16]. The recent development of a full-field laser Doppler imaging [22] is promising in that it reduces measurement time but it has yet to be proven in a clinical setting.

Laser speckle contrast imaging (LSCI), similar to LDI, constructs a color-coded map of the investigated area from dark blue to green, yellow and red showing low and high perfusion regions, respectively. Perfusion is measured in arbitrarily defined perfusion units (PU) [23]. Although both LDI and LSCI use laser light to estimate perfusion, the principle of measurement differs between the techniques. In LSCI, a divergent laser beam illuminates a rectangular area of tissue, typically 20 × 20 cm. In this area, a speckle pattern arises as a result of constructive and destructive interference of laser light [24,25]. When the light is scattered off moving red blood cells, spatial and temporal fluctuations in the speckle pattern arise [24,25]. Several image frames are acquired of the speckle pattern, and any fluctuations in the pattern causes blurring in the image frames [23–25]. The degree of blurring is quantified and is proportional to perfusion in the tissue [23–25]. The final image is a computed by calculating the mean of multiple individual frames, and total acquisition time ranges from a fraction of a second to a few seconds, depending on the required image quality [25].

We have previously described the complex temporal dynamics in perfusion seen in scalds depending on the depth of the burn [26]. However, the accuracy of LSCI in predicting burn healing time has not been studied. The primary aim of this study was to determine the accuracy (sensitivity and specificity), as well as the positive predictive value (PPV) and negative predictive value (NPV) of LSCI in the assessment of the healing time of scalds. We hypothesized that at specific measurement times, specific perfusion values can be used as cut-off values to predict the need for surgery. We also hypothesized that a greater sensitivity and specificity can be achieved when perfusion is measured at two occasions; one early measurement between 0 and 24 h after injury, and one between 72 and 96 h after injury. Furthermore, we compared the accuracy of LSCI with the accuracy of clinical assessments performed by experienced burn surgeons.

2. Methods

2.1. Study population

Perfusion measurements were done using LSCI in pre-pubertal children with scalds who were admitted to the intensive burn care unit at Linköping University Hospital, or who were treated as outpatients in the same clinic. Patients were only included if a perfusion measurement had been made at either 0–24 h or 72–96 h after injury, or both. This requirement resulted in a total of 45 patients (19 of whom were female). Their mean age was 2.2 (range 0.8–8.6) years and none of the patients had any underlying medical condition.

All patients initially received conservative treatment and a formal surgery decision was not made until 14 days after injury in accordance with local clinical practice. Surgery was done when the treating surgeon predicted that a wound area would take 21 days or more to heal. The same surgical procedure was used for all cases: sharp excision and autologous grafting of split thickness skin, usually meshed. Because 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.

2.2. Equipment

We used a laser speckle contrast imager (Pericam PSI, Perimed AB, Järfälla, Sweden) to measure perfusion. The system uses a divergent laser beam with a wavelength of 785 nm to illuminate the tissue, and creates a speckle pattern in 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 [27].

We set the image size to correspond to a 12 × 12 cm area of skin, kept the distance between the camera and the skin