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Cutaneous microcirculatory assessment of the burn wound is associated with depth of injury and predicts healing time

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ARTICLE INFO

Article history:
Accepted 24 June 2009

Keywords:
Burn microcirculation
Laser Doppler
Wound healing

ABSTRACT

Rationale: Current trends for the treatment of deep partial thickness and full-thickness burns include early excision and skin grafting. In this study we retrospectively evaluated the ability of Laser Doppler Flowmetry (LDF), taken within 24 h of the burn to predict: (1) burn wound depth and (2) wounds which would heal in less than 21 days.
Method: The Laser Doppler Flowmeter (O2C, LEA Medizintechnik, Germany) was employed to non-invasively measure the cutaneous microcirculation of 173 selected areas on 28 patients who suffered burns.
Results: A distinct association between initial flow (<24 h after burn injury) and the clinical assessment of depth of burn wounds was observed. Wounds demonstrating an initial blood flow of >100 AU were, in 93.1% of cases, correctly (positively) predicted for spontaneous healing within 21 days. A blood flow of <100 AU (negatively) predicted in 88.2%, those wounds which would not go on to heal within 21 days. Sequential measurement analysis (<24 h, 3 days after injury and 6 days after injury) revealed no significant decrease in skin perfusion velocity or flow rate.
Conclusion: LDF can provide immediate results for early determination of burn wound depth and is useful in selecting patients for conservative treatment of their burn wounds.

1. Introduction

It is generally accepted that deep partial thickness and full thickness wounds require excision and skin grafting in order to reduce the risk of infection, decrease hypertrophic scar formation, and shorten hospitalization time. Clinical decision making, in concert with early excisional strategies, require that an accurate and very early assessment of burn wound depth be made. It is well documented that protracted healing times exceeding 3 weeks are associated with the development of hypertrophic scarring [1,2]. Inaccurate clinical assessment of superficial partial thickness wounds on the other hand may lead to unnecessary skin grafting.

The most common determination is based upon a clinical assessment of the wound made by a surgeon or burn care provider using rather general criteria. This subjective

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0305-4179/$36.00
doi:10.1016/j.burns.2009.06.195

approach generally proves satisfactory for burns which are either very superficial or full thickness in depth [3]. Unfortunately, visual and tactile assessment of indeterminate depth burn wounds is by definition suboptimal and problematic even for the experienced surgeon. An analysis by Heimbach et al. [3] in 1984 found that even experienced surgeons only manage to correctly assess the depth of indeterminate burns 50% of the time. The same group [4] noted an accuracy rate of 70% in prediction of burn wound healing when all types of burn wounds were included.

Numerous efforts to increase objectivity in burn wound depth assessment have been advocated and include thermography, ultrasound, vital dye photometry as well as histologic assessment of burn wound depth [5]. To date, none of these methods have gained wide spread clinical acceptance. The use of Laser Doppler Flowmetry, first employed by Stern in 1975 for monitoring cutaneous microcirculation [6], may well be the most feasible clinical technique to address this problem. Micheels and associates [7,8] first reported on the use of Laser Doppler by a burn unit in 1984. The method is based on appreciable differences in cutaneous blood flow as evident in superficial partial thickness and deep partial thickness wounds. Since that time, several investigators [3,4,9–15] have measured skin blood flow in burned patients and found a close relationship between burn depth and flow level. Wounds which healed without grafting consistently demonstrated elevated basal perfusion levels which increased further over 72 h, while wounds that would eventually require grafting demonstrated lower initial perfusion levels with no obvious pattern of increase.

The use of Laser Doppler Flowmetry in the acute burn setting does pose several challenges related not only to cost and the sizable nature of the apparatus in present formulation, but also with regard to its efficacy when used in conjunction with opaque wound dressings. To improve its predictive value, several sequential measurements taken over the course of the first 3 after burn days are advocated [8,11,16,17], as is the technique of heating the area of interest to better determine wound depth [7,9,18,19].

We utilized a portable Laser Doppler Flowmeter to non-invasively and sequentially analyze cutaneous patterns of microcirculatory velocity and flow in both superficial partial thickness and deep partial thickness burn wounds. This information was used to establish cut-off values resulting in a high positive predictive value for spontaneous healing within 3 weeks after burn.

2. Materials and methods

173 burn wound regions of interest in 28 patients, ranging from 13 to 79 years of age (mean 42 years, 21 male, 7 female) were examined using the Laser Doppler O2C (LEA Medizintechnik Gießen, Germany). This portable Laser Doppler unit allows continuous and repeated measurements of a wound at skin depths of 2 mm and 8 mm, and enables the measurement of 4 parameters including blood flow, oxygen saturation, relative haemoglobin and velocity. Parameters of flow, velocity and relative haemoglobin are recorded as arbitrary units (AU).

All study patients were admitted to the Burn Unit at the BG Trauma Centre, Tuebingen between February 2003 and April 2004 and had burns ranging in size from 0.2% to 83% total body surface area (TBSA)(median 2% TBSA burn). Eligibility for the study was limited to patients meeting the following requirements: (1) burn wounds not older than 24 h, (2) burn wounds ranging in depth from superficial partial thickness to full-thickness injuries, (3) patients not catecholamine dependent, and (4) signed consent form.

Once informed consent was obtained, evaluation of wound depths was made by an experienced surgeon (OR) and target wounds were selected. Burn wounds were classified as (1) superficial dermal, (2) deep dermal, and (3) full-thickness burn wounds by one experienced burn physician. Pale white, non-blanching, and insensate wounds were considered full thickness wounds. In contrast, wounds with an erythematous wound bed, prompt capillary refill and severe pain on touch were categorized as superficial partial thickness burns. Deep partial thickness burn wounds are categorized as those between superficial partial and full thickness wounds. These wounds were characterized by limited sensation and evidence of reduced capillary refill or dermal bleeding. The surgeon was unaware of the laser Doppler values.

Superficial dermal burns were conservatively treated with collagenase ointment and Vaseline gauze. Full-thickness burn wounds were excised as early as possible and grafted with split thickness skin grafts. Indeterminate wounds were initially treated with Collagenase and Vaseline gauze until a clinical decision was made that these wounds would not heal in a 3-week period. In this case, wounds were excised and skin grafted.

Demographic characteristics, mechanism of burn injury, TBSA and planned wound management were collected. Laser Doppler measurements were recorded for each patient within 24 h of injury by the same person (KM). Measurements and photos were taken after the wounds had been gently cleansed with sterile saline and before a dressing was applied. Measurements were repeated again at 3 days, 6 days and 14 days after injury and collected for final analysis by KM and GB. Digital photos of the burn wounds were obtained at each time point.

The contralateral side matching the study site was measured by Laser Doppler Flowmetry as well, when it was not itself burned. The healing status of each wound was evaluated by the same surgeon daily. Wound evaluations continued until the surgeon determined either (1) the wound would heal or (2) the wound would not heal and required excision and grafting. At all times these decisions were independent from the obtained Laser Doppler measurements.

2.1. *Data analysis*

Data analysis was performed using the SPSS® 12.0 statistical software (SPSS Inc., Chicago, IL). The figures shown were plotted with the Origin software (OriginLab Co., Northampton, MA). A receiver operating characteristic (ROC) curve was produced to examine the trade-off between sensitivity and specificity and to choose the best flow value cutpoint to determine wound depth for spontaneous healing or grafting. To clinically evaluate the diagnostic efficacy of Laser Doppler