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Burn imaging with a whole field laser Doppler perfusion imager based on a CMOS imaging array

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ABSTRACT

Laser Doppler perfusion imaging (LDPI) has been proven to be a useful tool in predicting the burn wound outcome in an early stage. A major disadvantage of scanning beam LDPI devices is their slow scanning speed, leading to patient discomfort and imaging artifacts. We have developed the Twente Optical Perfusion Camera (TOPCam), a whole field laser Doppler perfusion imager based on a CMOS imaging array, which is two orders of magnitude faster than scanning beam LDPI systems. In this paper the first clinical results of the TOPCam in the setting of a burn centre are presented. The paper shows perfusion images of burns of various degrees. While our system encounters problems caused by blisters, tissue necrosis, surface reflection and curvature in a manner similar to scanning beam imagers, it poses a clear advantage in terms of procedure time. Image quality in terms of dynamic range and resolution appears to be sufficient for burn diagnosis. Hence, we made important steps in overcoming the limitations of LDPI in burn diagnosis imposed by the measurement speed.

1. Introduction

Proper determination of the burn depth is crucial for the choice of the optimal wound treatment. In burns with an intermediate depth (also called partial thickness burns), the early prognostication of the likely burn wound outcome is difficult in the first days after injury [1,2]. In these intermediate burn depths, even experienced burn surgeons have an accuracy of their clinical assessment of burn depth of 60–80% [3–7]. In literature several potential objective methods to determine burn depth in an early stage after injury are reported, one of which is laser Doppler perfusion imaging (LDPI).

The superficial partial thickness burns have a more active microcirculation compared to normal 'unaffected' skin, while the microcirculation in deep partial thickness burn wounds is impaired or lost [8]. These differences are used in the burn assessment with LDPI: the superficial partial thickness burns show perfusion values greater than those of unaffected skin, whereas the deep partial thickness burns have perfusion values lower than unaffected skin [9,10].

Various researchers investigated the accuracy of LDPI measurements in burn diagnosis and showed a high accuracy [2,11–14] which makes LDPI a powerful tool in the field of burn depth assessment.

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Most commercially available laser Doppler Perfusion imagers are scanning beam devices that require patient inactivity for a few minutes. Since a vulnerable group of burn patients is younger children there is a need for a faster full-field imaging system like Laser Speckle Contrast Analysis (LASCA) [15] or LDPI with high speed cameras [16,17]. LASCA has the disadvantage that the relation between the contrast and the perfusion is unknown, whereas LDPI has proven to be useful in burn care. The Twente Optical Perfusion Camera (TOPCam), a novel laser Doppler Perfusion Imager, reduces the total acquisition time to just 38 ms. [18]. The TOPCam has a short acquisition time thanks to the use of a high speed CMOS camera, in combination with illumination of a large tissue area. Another advantage of this device is its ability to render photographic images of the tissue site with the same sensor, which makes it easy to merge the perfusion and topographic images.

The aim of this study was to evaluate the capability and efficacy of the TOPCam to measure perfusion differences in burn wounds. Since it is reported that for example blisters, curvature and crusts can influence the perfusion values in the LDPI measurement [8,10], the effects of different wound appearances are investigated and also a comparison with a commercial scanning beam LDPI device, a PIM II system (Permed AB, Sweden), is performed.

2. Subjects and methods

2.1. Patients

In the period between June-August 2007 inpatients and outpatients of the Burn Center in the Martini Hospital Groningen (the Netherlands) were asked to participate in the study on a strictly voluntary basis. Patients with psychiatric problems, multi-system trauma and children under 16 years old were excluded. For safety reasons no measurements were performed on burns on the head of a patient.

The study was approved by the Medical Ethics Committee of the Martini Hospital.

2.2. Equipment

Our whole field LDPI device (the TOPCam), including its signal processing, is described in detail in reference [18]. The TOPCam uses a diffused laser beam (400 mW, $\lambda = 671 \pm 0.1$nm, class 2M) that illuminates a tissue area of 5×5 cm^2 up to 15×15 cm^2 at once. The used CMOS chip has 1024×1024 pixels but only an area of 128×128 pixels is used; each pixel acts as an individual detector. The whole setup was mounted on a trolley with an articulated arm. The microcirculatory flux parameter measured with the TOPCam is the DC-normalized first moment of the power spectrum.

The CMOS camera also provides a black-and-white photograph from the same location as the perfusion image. The taken photograph visualizes a larger area than the measured area and indicates the measured area for orientation purposes afterwards.

The measurement control and signal processing are performed by LabView 8.5 (National Instruments). The range of the color scale of the perfusion images is set in such a way that the lowest and highest 0.5% values are not taken into account, to avoid the influence of some faulty pixels.

The commercial scanning beam LDPI system available in the Burn Centre of the Martini Hospital is a PeriScan PIM II System (Perimed AB, Sweden) with a class 2 laser with a maximum output power of 1 mW, a beam diameter of 1 mm and a wavelength of 670 nm. The system can measure up to 64×64 measurement points in a maximum scan area of approximately 30×30 cm^2. It has one photodetector to detect the backscattered light, the measured parameter was the DC-normalized first moment of the power spectrum, expressed in manufacturer specific Perfusion Units. The color scale of the perfusion images is set to a fixed minimum and maximum for interpretation by the physician. The limits of this scale are determined by earlier research about the perfusion values in different types of burns [8].

2.3. Clinical methodology

The TOPCam LDPI measurements and matching digital photos were all made by the first author. In the first days post burn, all wounds were treated with Flammacerium©; LDPI measurements were performed after cleaning the wound, prior to applying new cream and bandaging. The TOPCam imaging head was situated 41 cm above the wound surface, observing the wound as perpendicular as possible (see Fig. 1 (c)). The spot size was set to 10×10 cm^2 and a color photograph was taken with a digital camera for extra orientation purposes afterwards. The iris of the system was adjusted manually to have a maximum intensity of around 85–95% of the saturation level (displayed on the screen by the Labview program). During the measurements the room illumination was turned off and curtains or lamellas were closed to minimize the influence of ambient light on the measurement. The patient was not shielded from the laser light and therefore was wearing special protecting glasses (Laser Vision, L5, 660–710 nm).

The total measurement procedure resulted in an interruption of the nursing process for approximately 5-10 minutes, depending on the number of measured areas. On each site the measurements were made in quintuple to check the reproducibility of the results later. If the patient and the available time allowed, the wound was measured with the PIM II system as well (see Fig. 1(a) and (b)). Wounds with various etiologies were measured and if possible normal skin was included in the scanned area.

Besides showing that the system is able to measure perfusion differences in burn wounds, special attention was paid to wound appearances like blisters, dead overlapping skin and crusts. Although not the target group of LDPI systems, also measurements on full thickness burns were done to check if areas where no superficial perfusion is expected indeed do not show perfusion.

3. Results

In total 1023 laser Doppler perfusion images were made of 37 burn wounds of 23 patients (5 women, 18 men). The range of age was 16–66 years (mean: 37.1, sd: 15.2), the range of the total