Laser Doppler Analysis of Blood Perfusion in Burn Wounds

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ABSTRACT

Objective: Laser Doppler Flowmetry (LDF) is a non-invasive tool for immediate measurement of cutaneous circulation which has been satisfactory applied in burn wound depth assessment. With variety of LDF models and assessment methodology, the standardization of LDF and criteria of burn wound depth diagnosis remain an inconclusive topic. Our study aimed to provide analytical data of LDF in burn wound assessment. This protocol was approved by the Institution Ethics Committee (Certificate of approval no. Si 017/2006).

Methods: From January 2006 to May 2007, cutaneous perfusion measurement with LDF model LASERFLO BPM2® (Vasamedics, USA) in day 1,3,5 and 7 were recorded and analysed. The data were analysed with a one-way ANOVA test.

Results: The data included 53 burn areas in 6 patients. The patients' mean age was 26.5 (range 2-48) years. There were 22 areas of superficial second degree burn, 20 areas of deep second degree burn and 11 areas of third degree burn. The LDF at the burn area revealed 100% sensitivity, 87.5% specificity, 92.5% PPV and LDF ratio demonstrated 92.0% sensitivity, 50.0% specificity, 73.0% PPV whilst early clinical assessment at first post burn day had 67.0% sensitivity, 87.5% specificity, 89.0% PPV.

Conclusion: The laser doppler flowmetry is a reliable device in determining burn wound severity. With high correlation in measurement of LDF perfusion data at burn area and LDF ratio to clinical diagnosis, this method helps as an adjunctive procedure to diagnose the degree of burn in early post burn day. The more accurate burn wound assessment can facilitate the optimal wound management and fluid resuscitation for burn patients.

Keywords: Burn; burn wound assessment; laser doppler flowmetry

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Early debridement of deep second degree and third degree burns has been accepted as a way to reduce the infection rate, system inflammatory response, hypertrophic scar, scar contracture and hospital stay[1]. However, the initial clinical assessments are problematic and not precisive. Many procedures were established to increase the accuracy of the assessment; for example vital dyes straining, ultrasonography, wound biopsy, light reflectance, nuclear magnetic resonance imaging, indocyanine green fluorescence, thermography or laser doppler flowmetry[2,3].

Laser doppler flowmeter (LDF) is a device for measurement of skin circulatory blood flow which was first reported by Stern et al in 1975[4]. The clinical modifications of LDF, with various types of LDF probes[2,5], have been introduced in other fields to monitor blood flow such as in microvascular replantation and free flap surgical sites, nervous system and dental procedures. With the utilization of a LDF wavelength of 780 nm, it is possible to measure the cutaneous circulation at the levels of arterioles, capillaries and dermal plexus postcapillary venules (approximate depth 1 mm to 1.5 mm)[4].

Advantages are its non-invasiveness, ease of the procedure and ability to assess in the initial day and also during the monitoring period, which make the LDF a useful device for burn wound assessment. The more precise evaluation of burn wound depth would lead to accurate diagnosis and appropriate treatment selection such as a mere wound dressing for the superficial degree burns and the early debridement with skin grafting for deep second and third degree burn wounds. With varieties of LDF models, probes and assessment methodologies, the standardization of LDF and criteria of burn wound depth diagnosis remains an inconclusive topic. This present study aimed to provide analytical data of LDF in burn wound assessment.

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Fig 1. Model LASERFLO BPM2® and probe number PD434 ; Vasamedics, USA.

Fig 2. Post burn day 1, Left and post burn day 14, Right.

MATERIALS AND METHODS

This study protocol was approved by the Institution Ethics Committee (Certificate of approval no. Si 017/2006). The study was conducted in burn patients who were admitted to the Burn Unit, Siriraj Hospital, excluding those who were in the conditions which the cutaneous blood flow would be altered, for example those with unstable vital signs, hypotension or known peripheral vascular diseases. All patients gave informed consent. The patients' wounds were investigated and assessed for their severity by using the LDF, (model LASERFLO BPM2® and probe number PD434; Vasamedics, USA), as shown on Fig 1, to measure the level of blood circulation at the burn area comparing to the non-burn areas adjacent or contralateral to the injured sites.

At each skin area, the blood flow measurement was done once a day at day 1, 3, 5 and 7 post burn event. The LDF measurement data were also compared with the clinical assessment at day 14. Clinical assessment at day 14 has been set as the gold standard of diagnosis which is classified into superficial second, deep second and third degree burn (Table 1)[6].

The mean and standard deviation of blood circulation levels at the 14th day of each category were calculated and compared. The one-way analysis of variance (ANOVA) was used to test for a statistically significant variation. A p-value of less than 0.05 is considered as significant statistically.

RESULTS

From January 2006 to May 2007, fifty-two burn areas in six burn patients, (including three flame burns, two scald burns and one electrical burn), were recruited. The patients' mean age was 26.5 (range 2-48) years. The injured sites were at the upper extremity region (17 sites, 32.7%), the lower extremity region (17 sites, 32.7%), the trunk region (15 sites, 28.8%), the perineal region (3 sites, 5.8%) and the facial region (1 site, 1.9%).

The final clinical assessment of all burn areas on their 14 days provided the following results: twenty-two areas of superficial second degree burn, twenty areas of deep second degree burn and eleven areas of third degree burn. The means of laser doppler flowmetry levels in each burn area and the ratio of burn to non-burn area for categorized burn degree are shown in Table 2.

With the one-way ANOVA test, the results of the means LDF and ratio of LDF measurement showed statistical significance comparing between each categorized burn wound group ($p = 0.001$ and 0.02 respectively).

The LDF measurement data were grouped by their means and standard deviations and determined the cut-off values which results in: superficial second degree burn for wounds with perfusion more than 25 PU, deep second degree burn for wounds from 5 to 25 PU, and third degree burn for wounds less than 5 PU. The accuracy of the LDF measurement with the grouped data were shown in Table 3. The accuracy of initial clinical assessment (first day), means of laser doppler flowmetry perfusion levels in each burn area and the ratio of burn to non-burn area compared with final clinical assessment of the wounds on their 14th day are shown in Table 4.

Fig 2 showed is an example of LDF measurement in clinical application, from a 36 year old male patient, who suffered from 40% scald burn. At the circled area on his left wrist, first day clinical assessment indicated a third

TABLE 1. Burn wound classification[6].

Superficial second degree burns	Blistered or appear pink, and have intact epithelium and dermal appendages. The regeneration is complete within 10 to 14 days.
Deep second degree burns	Often appear white, but are soft and resilient. The entire epithelium and dermal papillae are destroyed but some hair follicles and sweat glands survive, from which epithelialization occurs. Healing may take three to four weeks and skin quality is frequently poor, resulting in hypertrophic scar formation.
Third degree burns	Brown and dry, and have thrombosed vessels. The eschar is unyielding and hard. The entire epithelium and dermis are destroyed and any spontaneous healing that occurs is due to wound contraction.

TABLE 2. Measurement of blood flow by laser doppler flowmetry.

Degree Burn #	LDF at burn area †		LDF ratio ‡	
	Mean±SD	Range	Mean±SD	Range
Superficial second *(n=22)*	37.47±16.81	10.90-91.00	8.09±8.34	2.75-39.63
Deep second *(n=20)*	22.21±8.70	10.67-43.67	4.48±2.53	2.16-13.87
Third *(n=11)*	2.15±1.31	0.41-4.73	0.52±0.25	0.12-0.95
	p-value = 0.001*		p-value = 0.02*	

determine at post burn day 14
† *LDF measured in Perfusion Unit (PU)=ml LD/min/100 gm tissue*
‡ *ratio of burn area to non-burn area*
* *statistically significant (p<0.05)*

degree burn, whilst the mean LDF was 36.33 PU which was determined as superficial second degree burn and the final evaluation was confirmed as superficial second degree burn. (Fig 2)

DISCUSSION

Yeong et al.[7] reported 70% physician predictive accuracy from early clinical assessment of burn wounds. Park et al.[8] also reported 67% sensitivity and 87.5% specificity of clinical assessment at the first 72 hours post burn period. Burn wound biopsy was accepted as one of the gold standard in determining burn depth but the disadvantages are the addition of a new wound to the previous injury site and the time delay in examination process. Thus, the biopsy method was encouraged only in research groups and in full thickness degree burn patients who require surgical debridement. Other methods including vital dye staining, ultrasonography, indocyanine green fluorescence, thermography, light reflectance and nuclear magnetic resonance imaging, are being investigated for their clinical application.

In 1989, O'reilly and colleagues[9] reported 96.4% accuracy of LDF in 24 hours post burn period if the measurement data were less than 1.4 PU. Waxman et al.[10] reported 100% specificity of LDF in the 48 hours post burn period for the wound which spontaneously healed within 21 days but only 75% specificity for wound that did not heal in 21 days. Atiles and Park et al.[8,11] applied the LDF measurement in burn depth assessment and aimed to address the specific range for each burn wound severity. Regarding to various LDF models which were utilized in each clinical series there is no standard objective point for burn wound categorization and their reliability varied among individual investigators.

This present study reported LDF measurement data from LDF model LASERFLO BPM2® and probe number PD434 in a series of 52 burn areas in 6 patients. The results showed that the LDF perfusion data and ratio of burn-to-non-burn LDF measurement were significantly different among different burn wound groups categorized by burn degree or severity (p=0.001 and 0.02 respectively; Table 2). The range of LDF data for assessment of burn wound severity was calculated based on their means and standard deviations which resulted in: superficial second degree burns for wounds with more than 25 PU, deep second degree burn for wounds from 5 to 25 PU, and third degree burn for wounds less than 5 PU. Their specificity and positive predictive value were as high as 100% in the third degree group as shown in Table 3. In the second degree groups the sensitivity is still in the range of 70-95%.

The LDF measurement needs precise anatomic site mapping to monitor the burn wound progression. We encourage this method in patients with good cooperation and stable vital signs. The precise location can be ad-dressed with medical photography and surface landmarks. The cost effectiveness of the LDF method requires further investigation. The authors have no financial conflict of interest in producing the study.

TABLE 3. The accuracy of the LDF measurement with ranged data comparing to final clinical assessment (fourteenth day).

Ranged LDF data / Burn degree	≤ 5.00 PU Third	5.01 - 25.00 PU Deep second	≥ 25.01 PU Superficial second
Sensitivity	100%	70%	95%
Specificity	100%	97%	81%
PPV	100%	93%	78%
NPV	100%	84%	96%

CONCLUSION

The laser doppler flowmetry is a reliable device in determining burn wound severity. With high correlation in measurement of LDF perfusion data at burn area and LDF ratio to clinical diagnosis, this method helps as an adjunctive procedure to diagnose the degree of burn in early post burn day. The more accurate burn wound assessment can facilitate the optimal wound management and fluid

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TABLE 4. The accuracy of initial clinical assessment (first day), means of laser doppler flowmetry levels in each burn area and the ratio of burn to non burn area comparing to final clinical assessment (fourteenth day).

Assessment method	Clinical (1st day)	LDF at burn area	LDF Ratio
Sensitivity	67%	100%	92%
Specificity	87.50%	87.50%	50%
PPV	89%	92.30%	73%
NPV	63.60%	100%	80%