

Laser Doppler imaging as a tool in the burn wound treatment protocol

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Abstract

Introduction: The main treatment of burns is early excision of injured tissues.

Aim: To compare two different methods of examination of burned patients: clinical burn depth examination (CDE) and laser Doppler imaging (LDI).

Material and methods: A prospective randomized study of 57 burn patients treated in 2009–2011 was carried out. The burned patients were randomized into a CDE group and an LDI group. The CDE and LDI scan were performed 72 h after injury, with the second and third CDE and LDI scan on the 7th and 14th day after the burn. Age, sex, length of inpatient stay, cost of burn treatment, burn depth, cause and localization of the burns were analyzed between the two groups.

Results: Fifty-seven patients were treated during 2 years. Thirty-two patients were in the CDE group and 25 patients were in the LDI group. Most of the patients were male (45 male vs. 12 female, $p < 0.001$). The age was similar between the males and the females (female: 46.4 ± 16.9 years vs. male: 46.3 ± 12.5 years; $p = 0.11$). The mean length of stay in hospital was significantly higher in the CDE group (47 ± 34.4 day vs. 25 ± 10.8 day; $p = 0.005$). The mean cost of treatment of burned patients was significantly higher in the CDE group.

Conclusions: The length of stay and cost of treatment of burn patients depends upon early diagnosis of the deep burns and well-timed surgical treatment of burn wounds.

Key words: laser Doppler imaging, perfusion velocity, burn depth measure.

Introduction

Trauma and burns are among the main sources of morbidity and mortality of the community in our days. Burns result in long inpatient stay and cause psychological problems [1, 2]. The main treatment of burns is early excision of injured tissues which reduce inpatient stay and decrease the costs of treat-

ment [3–5]. There are many methods to assess burn wounds, but clinical examination of burn depth is still widely used [6, 7].

Aim

The aim of this clinical study was to compare two different methods of examination of burned pa-

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tients – clinical burn depth examination (CDE) and laser Doppler imaging (LDI) – to estimate the impact of the methods on the length of patient’s stay in hospital and the costs of burn treatment.

Material and methods

A prospective randomized study of 57 burn patients treated in the University Hospital of Kaunas, Department of Plastic and Reconstructive Surgery, in the period 2009–2011, was carried out. The clinical burn depth examination and LDI scan were performed for all burn patients who agreed to participate in the study. Inclusion criteria for the clinical study were patients burned within 72 h, age 18–75 years, and agreement to participate in the study. Exclusion criteria were age > 75 years, pregnant burned women, mental disease, lack of agreement to participate in the clinical study, and burned patients with a critical condition of health who were treated

in the intensive care unit department. The patients were randomized 72 h after the burn. The burned patients were randomized into two groups: the CDE group and LDI group. Randomization of burned patients was done using envelopes with numbers inside them and a list on paper where numbers showed in which group the patients belonged. The CDE was performed by surgeons and the LDI scan was performed by a radiologist. A Moor LDLS laser Doppler line scanner (Moor LDLS Rapid laser Doppler blood flow imaging by Moor instruments) was used for the LDI scan. The distance between the burn wound and scanner was 15 cm and the scan angle was 90°.

The depth of the injured tissue was assessed during CDE and LDI scan. The depth of injured tissue was divided into superficial (I and IIA burn degree) and deep burns (IIB and III burn degree). The burn wound biopsy was performed by a surgeon in the same burn location to detect the correlation of find-

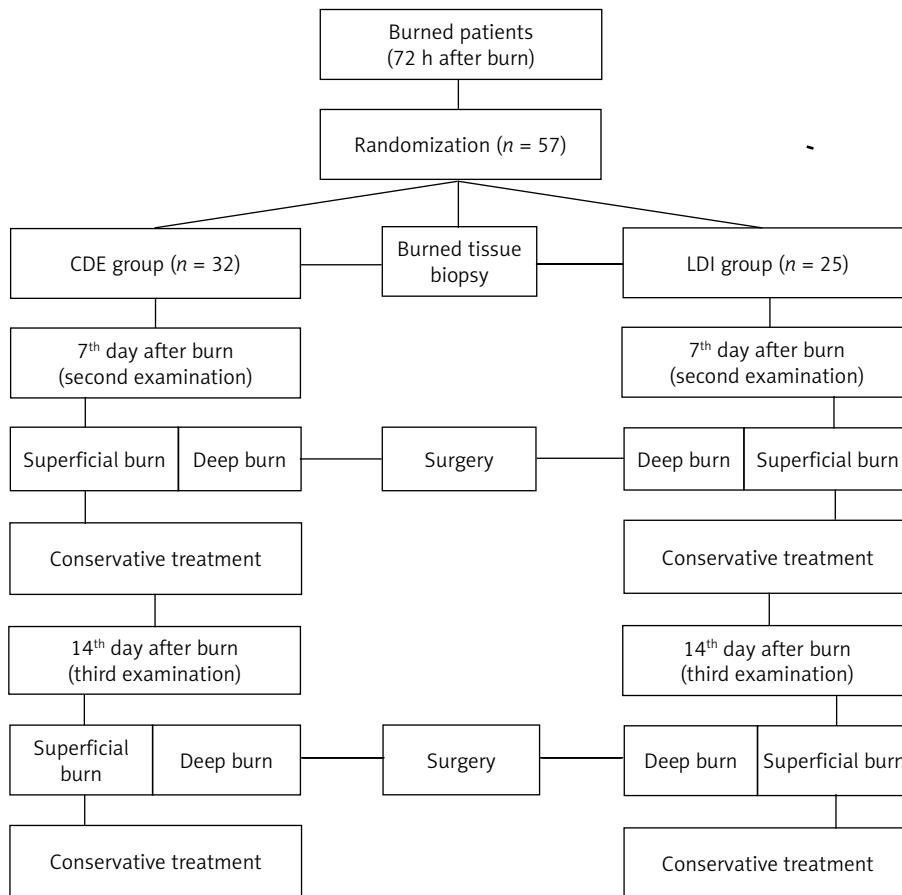


Figure 1. Scheme of patients’ investigation

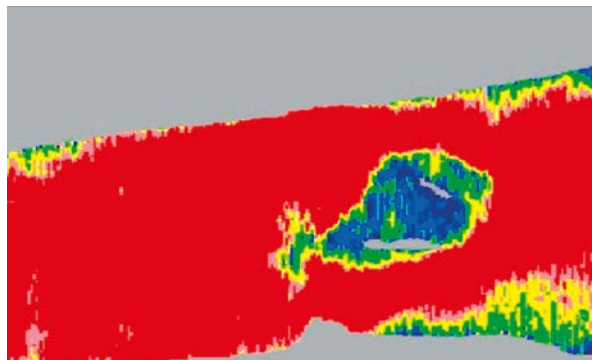


Photo 1. LDI scan (the arm). Burn tissue colors seen during LDI scan: blue and green color – low perfusion of injury tissue (deep burn), yellow color – moderate perfusion (between superficial and deep burn), and red color – higher perfusion of injured tissue (superficial burn)

ings of CDE and LDI scan. The worst burn wound was elected during CDE and LDI scan.

The CDE, LDI scan and biopsy were performed 72 h after injury, with the second and third CDE and LDI scan on the 7th and 14th day after the burn. If during a clinical examination a surgeon decided to perform necrectomy of the burn tissue 7 days after injury, the patients' participation in the clinical study was finished. The third clinical examination (CDE group) was performed on the 14th day after

the burn. The patient's participation in the clinical study was finished when the surgeon decided to perform necrectomy or normal tissue epithelization was seen at that time. The indication for surgery of patients of the CDE group depended on the clinical surgeon's experience. The indication for surgery of patients of the LDI group depended on LDI scan parameters. A deep burn was assessed when perfusion velocity during the LDI scan on the 7th and 14th day after the burn was 0–250 PU (perfusion units). The patients underwent surgery. If perfusion velocity was > 250 PU it was considered a superficial burn and patients were followed up and treated conservatively. The scheme of patient investigation is shown in Figure 1. The age, sex, length of inpatient stay, cost of burn treatment, burn depth, cause and location of the burns were analyzed between the two groups. The perfusion velocity of burn tissue was measured during the LDI scan, with results presented in perfusion units (PU). The LDI scan is shown in Photo 1.

The cost of burned wound treatment was calculated applying fixed valuation of service offering of the national health care system. Expense of treatment depended on the length of the patient's stay in hospital and operation or conservative treatment of the burn patient was done. The clinical study was approved by the Regional Ethic committee (No. BE 2-23; 11 Apr 2009).

Table I. General patient characteristics

Parameter		CDE group (n = 32)	LDI group (n = 25)	Value of p
Sex	Female	6	6	NS
	Male	26	19	
Age, mean ± SD		47.5 ±13.9	44.8 ±12.7	NS
Burn width (%)		19.5 ±9.9	18.2 ±14.5	NS
Cause of burn	Flame	27	16	–
	Hot water	4	5	–
	Hot steam	–	1	–
	Chemical sub.	1	3	–
Burn depth	I	1	3	–
	IIA	9	11	–
	IIB	8	9	–
	III	14	2	–

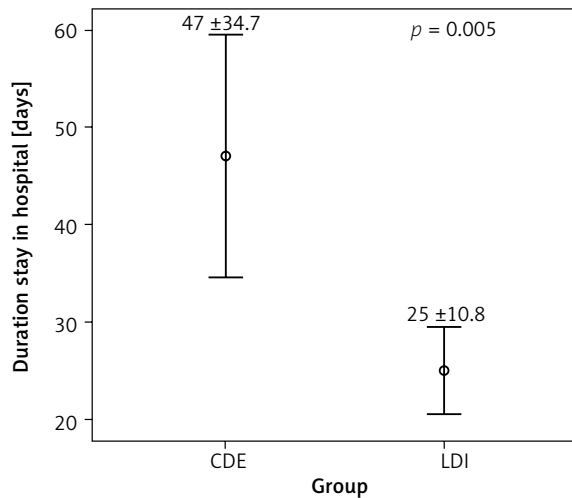


Figure 2. Length of patients' stay in hospital of the different groups

Statistical analysis

Statistical analysis was performed using SPSS (Statistical Package for Social Sciences) for Windows. Differences between means were evaluated using Student's *t* test for parametric criteria and the χ^2 test was used for nonparametric criteria. The Mann-Whitney test was used for small samples. A *p* value of < 0.05 was considered statistically significant.

Results

Fifty-seven patients were treated in the Department of Plastic and Reconstructive Surgery during 2 years. Thirty-two patients were in the CDE group and 25 patients were in the LDI group. Most patients were male (45 male vs. 12 female) and there was a significant difference ($p < 0.001$). The average age of the burned patients was 46.3 ± 13.4 years. The age of males and females was similar (female: 46.4 ± 16.9 years vs. male: 46.3 ± 12.5 years; $p = 0.11$). There was no significant difference comparing age and sex between the two groups. Thirty-eight patients (66.7%) were smokers (35 males and 3 females). The main cause of burns was flame – 43 cases (75.4%). Thirty-three patients (57.9%) had deep burns. The general patients' characteristics are shown in Table I.

LDI scan correlated with biopsy in 22/25 patients (88%), while clinical investigation correlated with biopsy only in 23/32 patients (71.9%).

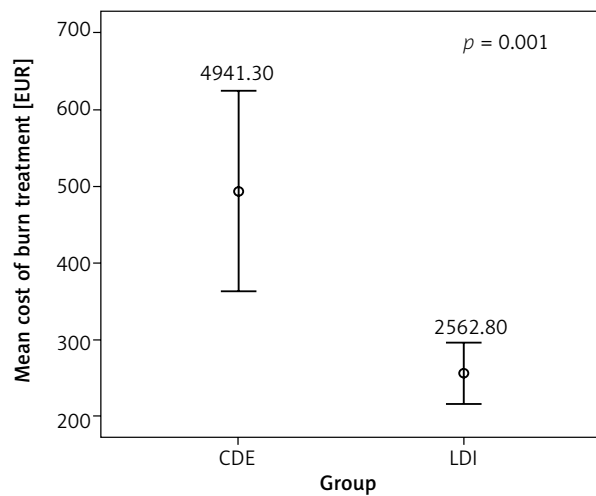


Figure 3. Cost of burn treatment of the different patient groups

The mean length of stay in hospital was significantly higher in the CDE group compared with the LDI group (Figure 2). The mean cost of treatment of burned patients was significantly more expensive in the CDE group (Figure 3). The patients from our database were divided into 4 subgroups: superficial and deep burn subgroups and conservative and surgical treatment subgroups. The length of stay in hospital and cost of treatment were analyzed in these subgroups and compared between different burn examination methods (CDE and LDI scan). The patients of the CDE group with deep burns and who underwent surgery had a significantly longer stay in hospital and received significantly more expensive treatment compared with patients of the LDI scan group (Table II).

The perfusion velocity of superficial burns was significantly higher compared with deep burns during the LDI scan at 72 h, 7th and 14th day after burns (287.3 ± 100.7 PU vs. 162.3 ± 120.9 PU, $p = 0.003$; 427.7 ± 220.9 PU vs. 120 ± 52.4 PU, $p = 0.004$; 658.7 ± 176.6 PU vs. 313 ± 87.7 PU, $p = 0.032$). Decrease of perfusion velocity of burned tissue during LDI scan investigation was the indication for surgery of burned patients (Figure 4).

Discussion

The relation between morbidity and mortality of burns and low socioeconomic status, profession, background and family status of patients has been proven by many social investigators [1, 8, 9]. Social

Table II. Comparison of length of stay in hospital and cost of treatment of different subgroups using different burn wound examinations

Subgroup	Group		Value of <i>p</i>
	CDE (n = 10)	LDI (n = 14)	
Superficial burns (length of stay in hosp.) [days], n = 24	19.1 ±12.3	22.5 ±10.9	NS
Superficial burns (cost of treatment) [EUR], n = 24	2326.54	2045.48	NS
	CDE (n = 22)	LDI (n = 11)	
Deep burns (length of stay in hosp.) [days], n = 33	59.7 ±33.8	28.3 ±10.2	0.001
Deep burns (cost of treatment) [EUR], n = 33	6129.83	3221.15	0.003
	CDE (n = 8)	LDI (n = 12)	
Conservative treatment (length of stay in hospital) [days], n = 20	26.8 ±11.5	22.4 ±7.5	NS
Conservative treatment (cost of treatment) [EUR], n = 20	2539.43	2016.93	NS
	CDE (n = 24)	LDI (n = 13)	
Surgery (length of stay in hospital) [days], n = 37	53.7 ±36.9	27.5 ±12.9	0.012
Surgery (cost of treatment) [EUR], n = 37	5741.92	3066.63	0.01

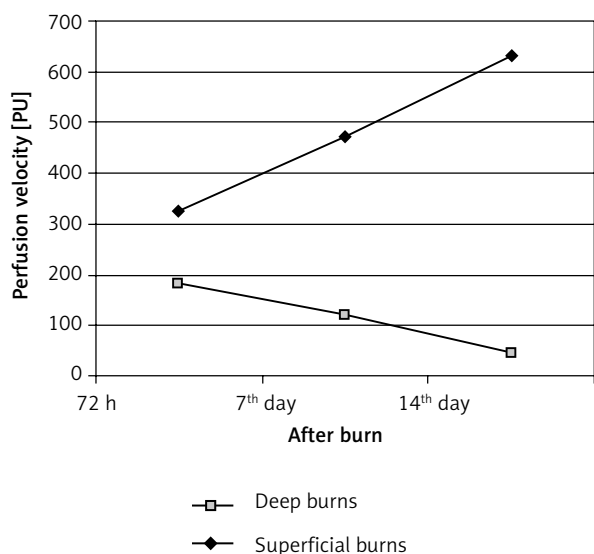


Figure 4. Perfusion velocity of different burns during patients' follow-up

studies showed that those living in poverty, with low salary, had a high risk of burns. The elderly possessed higher risk too [1]. Males have more burn injuries than females but mortality of burns does not depend on sex. Males have more serious burn injuries compared to females [2, 9, 10]. We did not analyze the social or economic status of burn patients in our

clinical study, but most of them were smokers and males. We had 43 patients of flame injuries and half of them were drowsing with a smoldering cigarette.

Early excisions of deep burn tissue reduce the length of stay and the cost of treatment, and decrease the risk of scar hypertrophy development [3–5, 7, 11]. Therefore it is important to assess and treat deep burns in the early period. Our clinical study proved that length of stay in hospital and cost of treatment of patients with deep burns were significantly different in the clinical burn depth examination group compared with the LDI group. There was no significant difference between the groups of patients with superficial burns comparing length of stay and cost of treatment.

Clinical burn depth examination is still popular in clinical practice [6, 7]. However, many clinical studies have shown that sensitivity of clinical burn depth examination varied from 50% to 72% compared to biopsy [3, 6, 11–13]. Burns of IIA degree can be assessed properly by means of clinical examination up to 66%, IIB degree (when the burn wound heals in up to 2 weeks) up to 77%, and IIB degree (when the burn wound heals in up to 3 weeks) only up to 50%. The clinical burn depth examination is a subjective method and it depends on the experience of physicians [6, 14].

Biopsy is the “gold standard” to diagnose the depth of burn wounds. The sensitivity of biopsy can

reach 100% [6, 7, 11, 15, 16]. The burn wound biopsy is recommended to be performed within 48–72 h after injury, because the blood perfusion of burn tissue can change during this period and impair the results [6, 7]. Biopsies of our clinical study were performed 72 h after injury, in order to prevent wrong results. The biopsy is an invasive technique and it can determine undesirable postoperative complications such as wound bleeding or suppuration [7]. Laser Doppler imaging scan is a non-invasive technique with sensitivity of 97%. Laser Doppler imaging scan allows early diagnosis of deep burns and reduces the length of stay and cost of treatment [3, 7, 11, 12]. Laser Doppler imaging scan did not correlate with biopsy of three patients from our study. The reason for this could be lubricants which were used during burn wounds dressing and were not cleaned carefully before the LDI scan. Deep burns opposite superficial burns were seen during the LDI scan. Clinical studies show that lubricants used for burn wound dressing reduce detection of blood perfusion during LDI investigation. The recommendation is to clean the burn wound carefully before the LDI scan [4, 11, 17–19].

The LDI scan is a non-invasive, painless and easily performed method for burn depth evaluation. Jeng *et al.* [11] proved that the LDI scan helps to assess early superficial burns and prevent unnecessary surgery. There are many discussions between authors about the technique of LDI scan. Some of them propose 15–30 cm distance between the scanner and burn wound and a scan angle of 90° [5, 7, 12, 20]. Other authors propose a distance of 50–70 cm and scan angle of 30–110° [4, 11, 13, 15]. We decided to choose the first recommendation for our clinical study.

The blood perfusion is higher compared to normal tissue in the superficial burn tissue and considerably less in the deep burn tissue. The burn wound blood microcirculation becomes worse within 12–24 h after the burn. The blood perfusion increases after 48 h and metabolic processes start in the burn wound [4, 12, 20]. Based on pathogenesis of burn tissue the recommendation to perform the LDI scan is 36–72 h after injury. The results can be false in the case of assessment of burn wound up to 24 h after injury [7]. In our clinical study we performed the first clinical burn depth examination and LDI scan 72 h after the burn.

According to Jeng *et al.* [11], if the perfusion velocity of the burn wound was 150–250 PU, the burn

was deep and these patients should undergo surgery. If perfusion velocity was > 250 PU the burn was superficial and these patients were referred for conservative treatment. However, successful results of conservative treatment were > 50% if perfusion velocity was > 250 PU [19–21]. The perfusion velocity of burn wounds was measured repeatedly by other authors [4, 7, 11]. The results were slightly different: perfusion velocity 0–250 PU in the case of deep burns and patients were referred for surgery. If perfusion velocity was 250–625 PU, conservative treatment was performed with follow-up and repeated LDI scan later. If perfusion velocity decreased after repeated LDI scan, surgery was indicated. If perfusion velocity was > 625 PU, conservative treatment and spontaneous epithelization of burn wounds finally appeared [4, 7, 11, 13, 16, 20]. We followed previous authors' recommendation for burned patients' indication for surgery in our clinical study. All patients of the LDI group with perfusion velocity less than 250 PU underwent surgery and patients were treated conservatively and followed up if perfusion velocity was > 250 PU.

However, the situation of patients with superficial (first degree burn) and deep (third degree burn) burns is certainly clear. The former are treated conservatively, while the latter undergo surgery. The most complicated situation is with IIA (superficial burn) and IIB (deep burn) degree burns. Sometimes IIA burns needs surgery and for patients with IIB burns enough conservative treatment and normal tissue epithelization is seen. It is necessary to determine a minimal perfusion velocity parameter during the LDI scan, which will enable one to choose the approach of treatment. We had 37 patients (20 patients with IIA degree burn and 17 patients with IIB degree of burn) with these degree burns in our study. Five patients of 20 with IIA degree burn were treated surgically and 4 patients of 17 with IIB degree burn were treated conservatively and normal tissue epithelization was seen. The mean perfusion velocity of these IIA patients was 264.80 PU and 305.50 PU of IIB patients. We did not calculate the prognostic parameter of perfusion velocity using a ROC curve, because we needed more cases of these types of patients.

Conclusions

Laser Doppler imaging scan is superior compared to clinical burn depth examination. Laser Doppler

imaging is effective for assessment of deep burns in the early period of injury. The length of stay and the cost of treatment of burn patients depend on early diagnosis of deep burns and well-timed surgical treatment of burn wounds.

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