**Research Article**

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# Estimation of Microcirculation Parameters in a Burn Wound for Prediction of Skin Grafting Outcomes After Tangential Necrectomy

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**BACKGROUND** Irregularity and mosaicity in the depth of the burn skin lesion limits the possibility of performing precision tangential necrectomy in the early stages after injury. Non-radical necrectomy leads to lysis of transplanted autodermal grafts. This problem is most relevant in the treatment of victims with extensive dermal and deep burns.

**AIM OF STUDY** To study the relationship between microcirculation parameters in the burn wound and the outcomes of autodermal transplantation after tangential necrectomy.

**MATERIAL AND METHODS** 74 patients with extensive skin burns included in the study underwent tangential necrectomy with simultaneous autodermal transplantation. All operations were performed early (up to 10 days) after injury before the formation of the demarcation line. Microcirculation parameters in the burn wound were studied by laser Doppler flowmetry before and after tangential necrectomy and in healthy skin of the same anatomical region.

**RESULTS** Statistically significant differences ($p \leq 0.001$) were found between microcirculation parameters in the center of the burn wound after tangential necrectomy and in the control area of intact skin. In this case, the results of autodermal transplantation were characterized by a skin engraftment rate of up to 60–70%. In those areas of the body where there were no differences between microcirculation parameters, the engraftment exceeded 80%.

**CONCLUSION** Assessment of microcirculation by laser Doppler flowmetry can be a reliable method for diagnosing the condition and viability of a burn wound after tangential excision of dead tissues in the early stages of treatment — before the formation of a demarcation line. The diagnostic technique is easy to use, but requires skills in working with a flowmeter, unification of such devices and methods for their use in the practice of surgical treatment of burns.

**Keywords:** burns, tangential necrectomy, autodermal transplantation, laser doppler flowmetry

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LDF – laser doppler flowmetry
PU – perfusion units

## INTRODUCTION

When providing assistance to victims with deep burns, the cornerstone is early surgical treatment as a pathogenetic way to treat burn injuries. Removal of the layer of dead tissues with simultaneous autodermal transplantation, according to the National Clinical Guidelines, is most optimally performed within 10–14 days, i.e. in the early stages after injury, in the period of burn toxemia and the onset of septicotoxemia, against the background of ongoing intensive therapy [1].

The key point of this surgical intervention is the formation of a viable wound surface for autodermal transplantation, since the existence of an extensive open wound leads to deterioration in the condition of the victim. To perform tangential necrectomy, early diagnosis of the depth of the burn is important. Visual irregularity and mosaic abnormalities of skin lesions lead to traumatization of its viable structures during surgery. In case of non-radical necrectomy, areas of necrosis can remain in the wound, what will lead to rejection of autodermal grafts. Clinical assessment in such observations is accurate only in 65% of cases, since differentiation between superficial and deep burns is difficult [2, 3].

Most authors note that the surgical outcomes depend on the depth of excision using a dermatome, the angle of inclination of its blade with respect to the excised surface, and the anatomical features of the body relief [4]. The analysis of the morphological picture of the excised layer of dead tissues after 146 tangential necrectomy surgeries indicate that this surgical procedure often leads to the removal of the entire dermis layer, which leaves its viable areas exposed and dry. This indicates the lack of selectivity of the intervention [5].

Autodermal transplantation on the postoperative wound surface after tangential necrectomy requires reliable criteria for the viability of the wound bed. Laser Doppler flowmetry has proven to be a highly informative method for diagnosing superficial and deep skin burns [6–10]. However, due to various technical approaches and possible interpretations of the obtained results, this method of diagnosing the depth of burns is recognized as quite subjective and is effectively used only in few burn centers.

In the present study, the relationship between microcirculation parameters in a burn wound after tangential necrectomy and the effectiveness of skin grafting was studied.

Aim and objectives of the research. To study the relationship between microcirculation parameters in the burn wound and the outcomes of autodermal transplantation after tangential necrectomy.

To achieve this aim, the following objectives were determined:

1. Using the method of laser Doppler flowmetry, to evaluate the features of microcirculation parameters of the burn surface after performing tangential necrectomy;
2. To study the microcirculation parameters of the burn surface after tangential necrectomy and similar parameters in the control area of intact skin, and also to determine the statistical significance of the identified differences;
3. To establish the relationship between the identified features of microcirculation parameters (in the wound and in intact skin) and skin grafting outcomes.

## MATERIAL AND METHODS

Microcirculation parameters were evaluated in 74 burn patients with extensive borderline and deep burns to subfascial structures, hospitalized to the Department of Thermal Injuries of the Saint-Petersburg I. I. Dzhanelidze Research Institute of Emergency Medicine in the period from 2017 to 2021. In case of burns deeper than the skin's own fascia, other types of necrectomy and/or amputation of limb segments were performed. The study does not include victims of electric current, as well as patients with a fatal outcome.

Surgical treatment of all burn patients was performed within 3–10 days after injury. Among the victims, the majority were men - 60 observations (81.1%). Their average age was 47.52±13.95 years. While the average age of women corresponded to 58.93±16.77 years. In men, the total area of the burn injury was 28.77% ± 17.66% of

the body surface (b.s.), while a deep burn was 17.79 ± 13.3% b.s.; in women, the distribution of the total area and the depth turned out to be similar: 30.07% ± 14.4% b.s. and 15.64±8.07% b.s., respectively. Early tangential necrectomy with simultaneous autodermal transplantation was performed on the area of 7.9±3.69% b.s. in men and 8.21±2.67% b.s. in women.

The most common damaging factors in burn patients were: flame - 61 victims (82.43%), hot liquid - 7 observations (9.46%), contact burns - 6 patients (8.11%).

To study the parameters of the microcirculatory bed of burn wounds, laser Doppler flowmetry (LDF) was performed using a LAKK-02 device (LAZMA, Russia). Registration of LDF-grams was carried out in accordance with Laser Doppler flowmetry of blood microcirculation: a manual for doctors edited by A.I. Krupatkin et al. (2005). The resulting LDF-gram is a generalizing characteristic of oscillatory rhythms which have their own frequency and amplitude. Its recording is accompanied by automatic calculation of standard statistical parameters. The research methodology is shown in Fig. 1.

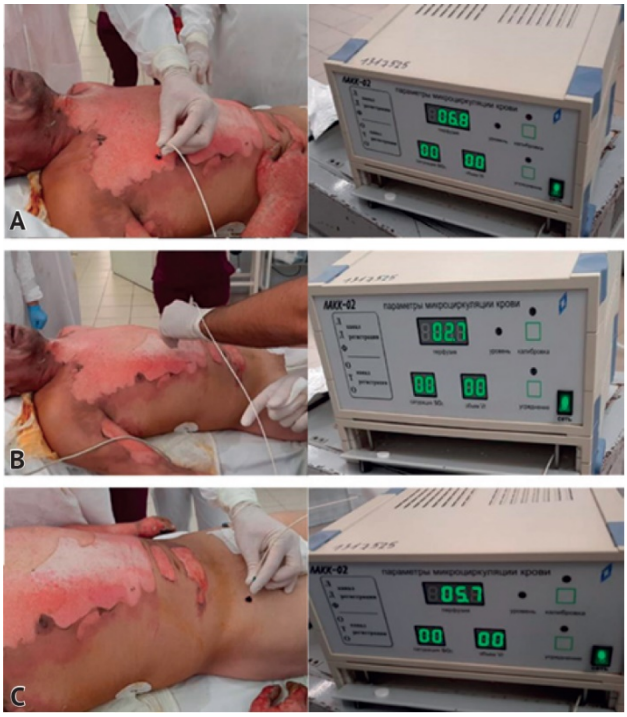


Fig. 1. Intraoperative study of microcirculation parameters: A — periphery of the burn wound (zone of superficial injury); B — the center of the burn wound (suspected zone of deep damage); C — unaffected skin on the same segment of the body (normal microcirculation parameters)

To diagnose the depth of skin lesions, LDF was used as a way to assess blood flow in the layers of the dermis. The volume of the probed tissue was determined by the location of the sensor's light guides and the optical parameters of the light probe which for the device used was 1 mm3. LDF-grams were registered in the operating room at room temperature (20–22°C). To obtain the control parameters of microcirculation, the LDF of the nearby intact skin or on the contralateral segment of the intact limb was assessed.

The study of a burn wound began from the periphery (a zone of superficial damage) and gradually moved deeper into the wound, recording microcirculation parameters along the path of the sensor. In the case of their decrease by more than 2 times from the norm in the wound, the boundary of a deep lesion was marked for subsequent tangential excision of this area of the burn wound. Repeated flowmetry in the same area was performed after tangential removal of the tissue layer. If the microcirculation was restored, the wound was considered suitable for autodermal transplantation. Based on the comparison of the obtained perfusion index in the postoperative wound surface with the microcirculation parameter in the skin of the intact area of the same localization, it was concluded that it was viable and suitable for autodermal transplantation.

For tangential necrectomy, dermatomes with both rotating and reciprocating blades were used, which allowed surgeons to more accurately dose the thickness of the excised tissue layer (from 0.3 to 1 mm). Capillary

bleeding from the wound bed did not always mean that it was ready for skin grafting, the fact confirmed by our experience. In addition to clinical data, LDF was used to assess the viability of the wound surface after tangential necrectomy. If the burn wound was represented by a dense scab and the microcirculation parameter was zero, then this indicated the death of all layers of the skin. In this case, tangential necrectomy was inappropriate and the surgery of choice in this area was fascial necrectomy.

The results of autodermal engraftment were assessed on the 7th day after surgery, which corresponded to the beginning of capillary germination into the transplanted tissue according to a 5-point scale for assessing the percentage of engraftment area: 90–100% — 5 points, 80–90% — 4 points, 70–80% - 3 points, 60–70% - 2 points, less than 60% - 1 point. This scale was chosen by us for a more detailed assessment of the results.

All the victims were divided into three groups depending on the localization of the burn area subject to surgical treatment: 23 operations on the trunk, 22 cases - upper limbs, 29 cases - lower limbs. On the head and neck, tangential necrectomy was not performed.

Statistical processing of the material was carried out using the MS Word, MS Excel and SPSS Statistics 17.0 software packages. The samples were compared by means with a standard deviation. Taking into account the small volume of the analyzed groups, when calculating the significance index, the nonparametric Mann–Whitney U test was used. The alternative hypothesis was accepted at $p<0.05$.

## RESEARCH RESULTS

It was established that the highest intensity and, accordingly, microcirculation parameter was recorded in the intact skin of the upper extremities. Its average value for the group was 6.02±0.95 perfusion units (PU), which corresponds to the norm. Before excision of the eschar, the burn wound (eschar) was characterized by a low microcirculation parameter of 1.48 ± 0.87 PU, which made it possible to consider this area as a zone of deep damage, subject to tangential necrectomy with simultaneous autodermal transplantation. Burn wound areas with 0 PU were subjected to fascial necrectomy during the intervention or later, but the results of autotransplantation were not evaluated in those cases, since they were not the subject of the study.

After excision of the scab, the microcirculation parameters practically returned to the normal values in all clinical observations of wounds of the upper extremities and averaged 5.41±0.83 PU for the group, which allowed surgeons to perform autodermal transplantation. There were no statistically significant differences between microcirculation parameters from the postoperative surface of the burn wound and from the nearby area of healthy skin.

When examining the microcirculation parameters in burn wounds of the lower extremities in the area of a suspected deep burn, the microcirculation parameter value was 0.58±0.49 PU, after necrectomy it increased to 2.87±0.43 PU. At the same time, in the control zone (healthy skin), this value was 3.18±0.52 PU. Statistically significant differences between the last two values were not obtained, which made it possible to consider the wound suitable for autodermal transplantation.

On the trunk, the value of microcirculation in healthy skin was 5.19±1.01 PU. In the area of a suspected deep burn, a value of 1.41±0.96 PU was obtained, which served as confirmation of the presence of a deep burn, the surgical treatment of which is possible using the tangential necrectomy technique.

After excision of the scab in the trunk area, the value of the microcirculation parameter was 3.9±0.82 PU. At the same time, the wound was visually ready for split-thickness skin grafting. Based on clinical data, autodermal transplantation was performed in those cases. Subsequently, during statistical processing, statistically significant differences were observed between the values of microcirculation in the center of the postoperative wound and in healthy skin.

The average values of microcirculation parameters in various anatomical zones, identified in the course of surgical treatment, are given in Table 1.

*Table 1*

**Parameters of skin microcirculation in various anatomical zones**

| Anatomical area of study | Microcirculation parameter (perfusion unit) (M±m) | | |
|---|---|---|---|
| | Healthy skin | Wounds before scab removal | Wounds after scab removal |
| Trunk | 5.19±1.01* | 1.41±0.96 | 3.9±0.82* |
| Upper limbs | 6.02±0.95 | 1.48±0.87 | 5.41±0.83 |
| Lower limbs | 3.18±0.52 | 0.58±0.49 | 2.87±0.43 |

Note: Mann-Whitney U-test — * differences between the values of "healthy skin" and "wound after excision" are significant at p≤0.001

On the basis of the 5-point engraftment rating scale, the average result for the group corresponding to a certain anatomical region was evaluated. In 22 cases of surgical treatment of deep burns of the upper extremities the result of engraftment after tangential necrectomy with simultaneous autodermal transplantation was 4.45±0.74 points (in most cases, an "excellent" result).

In the group of patients with deep burns of the lower extremities (29 cases), the average score was 3.93±0.65, which in most cases was characterized as a "good" result. In the third group of patients, where the burn zone covered mainly the lateral and posterior surfaces of the body, the average engraftment score was 2.35±1.11 points, which in most cases was "unsatisfactory", since clinically the wound looked ready for transplantation. Moreover, the thickness of the excised scab in some areas of the posterior surface of the body reached 3 mm.

The outcomes of tangential necrectomy with simultaneous autodermal transplantation, depending on the localization of wounds in the analyzed groups of patients, are shown in Table 2.

*Table 2*

**Autodermal engraftment in the observation groups**

| Anatomical area | Efficiency of the operation (point scale) | | | | | Total |
|---|---|---|---|---|---|---|
| | 1 point | 2 points | 3 points | 4 points | 5 points | |
| Upper limbs | 0 | 0 | 3 | 6 | 13 | 22 |
| Lower limbs | 0 | 0 | 7 | 17 | 5 | 29 |
| Trunk | 5 | 10 | 4 | 3 | 1 | 23 |
| Total | 5 | 10 | 14 | 26 | 19 | 74 |

When burns were localized in the upper extremity region, the high efficiency of skin grafting after tangential necrectomy was the most frequently recorded corresponding to 5 and 4 points — 13 (59.1%) and 6 observations (27.3%), respectively. The result of 3 victims (13.64%) of this group was estimated at 3 points.

In the group of patients who underwent surgery on the lower extremities, the analyzed parameter had lower values. So, according to the proposed scale, the result of autodermal transplantation was estimated at 4 points in 17 cases (58.6%), 5 points were noted in 5 victims (22.7%), and 3 points were recorded in 7 cases (24.14%).

The largest number of unsatisfactory results was noted in surgeries on the trunk: 1 point - in 5 burn patients (21.7%) and 2 points - in 10 victims (43.5%), 3 points - in 4 victims (17.39%), "good" result was determined in 3 (13.04%) and "excellent" only in 1 (4.35%) case.

Figures 2-4 show the stages of treatment of a patient with a dermal burn of the posterior surface of the trunk.

Fig. 2. Patient V., 43 years old. II–III degree flame burn 32% (15%) of the trunk, limbs. Stage of burn toxemia. Marking of deep and borderline burns was performed

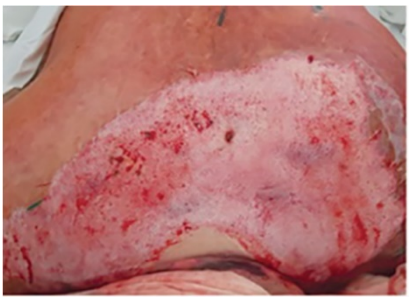

Fig. 3. Burn wound after tangential excision of the burn eschar

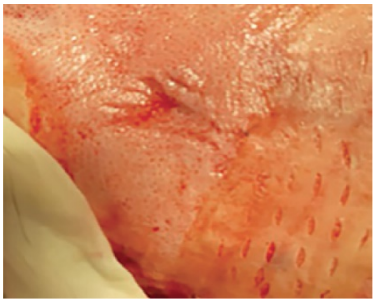

Fig. 4. An autodermal graft was placed on the deep burn area. Wound dressings were used on superficial lesions

## DISCUSSION

Based on the analysis, it can be concluded that the absence of differences between the value of microcirculation in the center of the wound surface after tangential excision of dead tissues and the value of microcirculation in the intact skin of the same body segment allows us to expect "good" and "excellent" results of autodermal engraftment on this postoperative surface.

On the contrary, statistically significant differences between the analyzed microcirculation parameter of the burn wound and the area of healthy skin are a poor prognostic sign for autodermal engraftment. This fact is an indication for the surgeon: it is necessary to remove the tissue layer of the burn wound once again to reach a viable area, or to refrain from skin grafting. Of course, in each case, one should proceed from the anatomical region, since the thickness of the epidermis and dermis varies significantly depending on localization: the back of the hand - 1.01–2.71 mm, the anterior surface of the forearm - 1.21–1.78 mm, - 1.89-2.10 mm, back surface of the forearm and shoulder - 2.28-3.04 mm, chest - 1.97-3.00 mm, back surface of the torso - from 2.66 to 4.76 mm. The deepening of necrectomy to the subcutaneous adipose tissue makes it impossible to perform autodermal transplantation, and its term is postponed until the formation of granulation tissue. On the back surface of the trunk using a dermatome with a blade pitch of 0.5 mm, it is possible to perform 5–6 passes along the wound surface until a viable layer is reached, which is characterized by the same values of the microcirculation parameter as in the adjacent area of unaffected skin. At the same time, if the burn is localized on the back of the hand, tangential excision of the scab with a blade pitch of 0.6 mm can be performed only once in order to avoid exposure of the extensor tendons during repeated pass of the dermatome blade.

Taking into account the literature data, we confirmed the normative indicators of the microcirculation state in young men's skin of the head, trunk and main segments of the upper and lower extremities [11, 12], but given the severity of the condition of the victims and possible changes in microcirculation, we preferred to use as a control microcirculation parameters in the unaffected area of the victim's skin. This fact allowed us to dispense with the creation of comparison groups to determine the normal values of the microcirculation parameter in pathology and in the norm. As experience has shown, it is not the specific values of the burn wound's microcirculation parameter that are important for engraftment, but the absence of differences between them and healthy skin.

## CONCLUSIONS

1. Based on the analysis performed, it can be concluded that the absence of differences between the values of the microcirculation parameters of the postoperative surface and the area of healthy skin provides a guarantee of its viability and suitability for autodermal transplantation with an engraftment rate of more than 80%.
2. Evaluation of microcirculation by laser Doppler flowmetry can be a reliable diagnostic method in the development of uniform criteria for assessing the state of a burn wound after tangential excision of dead tissues in the early stages - before the formation of a demarcation line.
3. This diagnostic technique is easy to use, however, it requires skills in working with a flowmeter, unification of devices and the development of an algorithm for its use in the practice of surgical treatment of burns.

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