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თანამშრომლობითა და მისი პატრონაჟით

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PREOPERATIVE DONOR ZONES PREPARATION OF PERFORANT FLAPS BY TRAINING PERFORANT VESSELS WITH NEGATIVE PRESSURE

Trofimov N.[1], Kryshen V.[1], Korpusenko I.[1], Nor N.[1], Korpusenko E.[1], Makarenko A.[2]

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Introduction. One of the key factors in achieving favorable treatment outcomes when planning reconstructive surgeries using perforant flaps is the choice of recipient vessels. The diameter of perforant vessels, on which flaps are most often formed, ranges from 1 to 1.5 mm. Their identification causes certain difficulties both at the planning stage and during the operation. Known methods of preoperative planning of perforant flaps using ultrasound sonography and Doppler, selective angiography, CT angiography [1-3]. A modern method of preoperative perforants location is dynamic infrared thermography, which makes it possible to identify perforant vessels after using functional tests [4-7]. The thigh area is the easiest area to eliminate a wound defect due to significant reserves of skin and soft tissues. That is why this site is widely used in plastic surgery for taking free microsurgical flaps, such as an anterolateral femoral flap (ALT flap) or a diagonal gracilis femoral flap (DUG flap) with a simple elimination of the donor zone [8-11]. At the same time, if there is a need for revascularization of open and initially infected deep anatomical structures, perforant local propellers, keystone flaps or free transplantation from remote donor sites can be used in this region [5,12,13].

The basis of our study was the task of preoperative preparation of donor areas by training arteries - perforants by applying the action of local negative pressure on the skin.

Purpose of research. Development of the most rational modes of action of negative pressure on the skin of the thigh for preoperative preparation of the donor zone for the formation of perforant flaps.

Materials and methods. The determination of the most rational modes of action of negative pressure on the skin of the thigh was carried out on a group of healthy volunteers (GHV) - 35 people: 17 women and 18 men aged 19 to 50 years. The studies were carried out on the basis of the burn department of the clinic in Dnipro, Ukraine in 2020-21. For preoperative location of perforants, dynamic infrared thermography (DIT) was used using a Flir ONE (USA) thermal imager for smartphones and tablets based on Android [7]. Local vacuum (VAC-action) was created using the AGAT-Dnepr negative pressure apparatus (Ukraine) by applying a polyurethane sponge to the anterior surface of the thigh.

Statistical data processing was carried out using a personal computer using software products STATISTICA 6.1 (StatSoftInc., serial no. AGAR909E415822FA) and Microsoft Excel (Microsoft Office 2016 Professional Plus, Open License 67528927) using methods of descriptive and analytical biostatistics and multivariate methods of statistical analysis [14,15].

Results and discussions. The examination was carried out in a room with a constant air temperature of 21-22°C, the subject was given a horizontal position and he adapted within 20 minutes. After adaptation, for better visualization of the projection zones of the perforant vessels, the skin of the anterior surface of the thigh was cooled by applying a gauze napkin 10 × 20 cm in size, folded in 10 layers, moistened with cold water at a temperature of 18-20°C for 15 minutes. After cooling, a thermal imaging examination was carried out, from 2 to 4 perforators were detected. After that, a local vacuum P = (-100 mm Hg) was created for 10 minutes. Then, immediately after the negative pressure apparatus was turned off, the perforant vessels were visualized and the number of perforants was counted using a thermal imager. The next stage of the study was aimed at increasing the negative pressure. The pressure varied from P = (-100 to -160 mm Hg), exposure time from 10 minutes to 20 minutes, 30 minutes, 60 minutes, 24 hours and 48 hours. The studies were carried out at the same time at the indicated time intervals - 60 seconds (immediately after the action of negative pressure); 20, 30, 60 minutes; after 24 and 48 hours. 60 seconds after the action of negative pressure on the anterior surface of the skin of the thigh, "hot zones" of an increase in local temperature are determined, with a temperature gradient ΔT=2.10 - 1.15 (95% 1.0 - 1.4) -30 minutes, the skin temperature drops to 31.19 (95% Confidence interval (CI) 32.0-32.6)°C, and against the background of this decrease, points of hyperemia appear 33.6 (95% 33.2-34.5)°C in different quantity, depending on the time and magnitude of the negative pressure, which persist for 24 - 48 hours (Fig. 1).

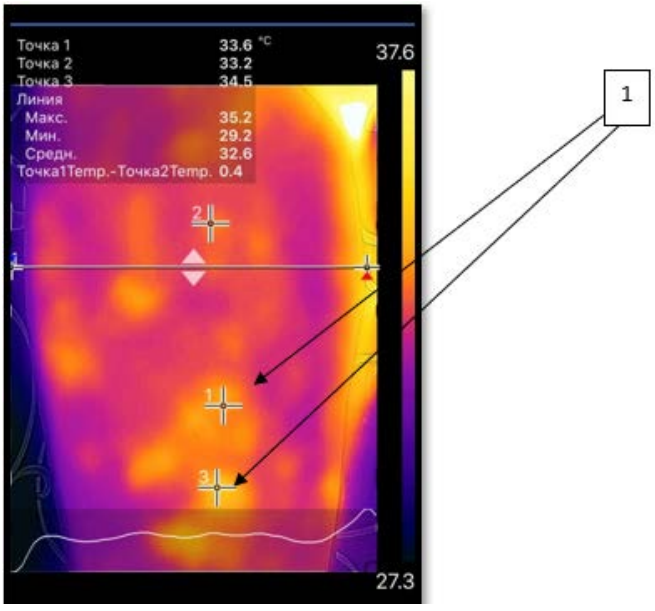

Fig.1. DIT of the skin of the anterior surface of the right thigh. The right thigh 30 minutes after the VAC-action, 10 perforants are determined.

As a result of the experiment, changes in the number of perforants depending on the duration of negative pressure were traced (Table 1).

The largest average number of perforants in the examined patients was observed after 30 minutes of VAC action - 12.0 (6.0; 12.0), which was statistically significantly higher compared to their number, which was detected after 10 minutes of negative pressure action ($p<0.001$). On average, according to the median values of 12 perforants after 30 minutes, the VAC-action remained after 20, 30 and 60 minutes after exposure and decreased only after 24 hours. Doubling the period of VAC - action to 60 minutes and no longer led to an increase in the number of perforants. Therefore, the optimal negative pressure time is 30 minutes when up to 10-12 perforants are opened. Accordingly, in the dynamics, depending on the time elapsed after the VAC- action, a pattern is observed: the largest number of perforants persists for 24 hours.

The number of certain perforants depends on the duration of the negative pressure: a direct strong relationship was found between the indicators ($rs=0.85$; $p<0.001$). Based on the results of the regression analysis, a non-linear power-law form of relationship between the duration of negative pressure and the number of perforants was revealed (Fig. 2), which was described by the equation ($p<0.001$):

$$y=11,23+0,22\times x-0,003\times x^2 \quad (1)$$

where y- is the number of perforants.

x- is the duration of the negative pressure in minutes.

Depending on the magnitude of the negative pressure, certain changes in the number of perforants were observed within 2 days (Table 2).

The smallest average number of perforants in the GHV group was observed at a pressure level of P= (-100 mm Hg) 24 hours after the VAC-action and at P=(-160 mm Hg) 48 hours later. The largest average number of perforants was detected at the pressure level P= (-130 mmHg) – 10.0 (8.0; 14.0), which was statistically significantly higher compared to their number under the negative impact of pressure P = (-100 mmHg) ($p<0.001$). The indicator was constant, the number of perforants was maintained during the entire observation period from 20 minutes to 48 hours.

Based on the results of the correlation analysis, the average strength of the correlation between the magnitude of the pressure of the VAC- action and the number of perforants was determined - $rs=0.56$ ($p<0.001$). According to the results of the regression analysis, the nature of the connection was refined, and it was determined that it has a non-linear power form of the connection (Fig. 3), which was described by the equation ($p=0.010$):

$$y=51,17-0,85\times x-0,031\times x^2 \quad (2),$$

where y- is the number of perforants.

x- is the level of negative pressure in mm Hg.

Thus, on the basis of the analysis, it was determined that the pressure P= (-130mm Hg) is the most optimal for opening perforants (10-12 pieces). What can be useful for using local negative pressure to "train" the perforant vessels of the donor site for 2-3 days before the transplantation of the perforant flap. VAK-action promotes the opening of perforants and improves blood supply to the donor area.

Perforant flaps are a step forward in the repair of soft tissue defects, they have opened a new era in reconstructive surgery and provide very important advantages in reconstructive surgery. However, there are risk factors that cause various complications. Therefore, when planning reconstruction, great attention should be paid to tissue blood supply [7,11,12]. Examination of the patient in the preoperative period most often begins with physical methods: determining the pulse, color, turgor, capillary filling of the skin. Additional information can be obtained using a handheld portable audio doppler. A well-known technique for preoperative location of perforants using dynamic infrared thermography (DIT) is a study with a

Table 1. Determination of perforants depending on the time of the VAC-action in the GHV (n=35) following the data of DIT - Me (25%; 75%).

VAC- action time	The number of perforants after the action of negative pressure after a certain period of time					
	60 seconds	20 minutes	30 min	60 min	24 hours	48 hours
10 min	3,0 (1,0; 3,0)	3,0 (3,0; 4,0)	3,0 (3,0; 3,0)	3,0 (2,0; 3,0)	3,0 (1,0; 3,0)	3,0 (1,0; 3,0)
20 min	4,0 (3,0; 4,0)	4,0 (4,0; 5,0)	4,0 (2,0; 4,0)	4,0 (1,0; 4,0)	2,0 (1,0; 3,0)	2,0 (0,0; 2,0)
30 min	12,0 (10,0; 12,0)*	12,0 (8,0; 12,0)*	12,0 (6,0; 12,0)*	12,0 (5,0; 12,0)*	10,0 (6,0; 11,0)*	8,0 (6,0; 8,0)*
60 min	8,0 (4,0; 8,0)*	8,0 (8,0; 10,0)*	8,0 (6,0; 8,0)*	8,0 (4,0; 8,0)*	6,0 (3,0; 7,0)*	4,0 (2,0; 4,0)
24 hours	6,0 (3,0; 6,0)*	7,0 (6,0; 8,0)*	6,0 (4,0; 6,0)*	6,0 (3,0; 7,0)*	4,0 (3,0; 4,0)	4,0 (2,0; 4,0)
48 hours	6,0 (2,0; 6,0)*	6,0 (6,0; 8,0)*	6,0 (2,0; 6,0)*	4,0 (2,0; 6,0)	4,0 (2,0; 4,0)	4,0 (1,0; 4,0)

*Note. * – p<0.001 according to the Wilcoxon test compared with a level in 10 minutes of VAC-action.*

Table 2. The number of perforants depending on the pressure value of the VAC - actions in the GHV (n=35) according to the DIT data - Me (25%; 75%).

Pressure level (mmHg)	The number of perforants after the action of negative pressure after a certain period of time					
	60 seconds	20 minutes	30 minutes	60 minutes	24 hours	48 hours
-100 mmHg	4,0 (2,0; 6,0)	4,0 (3,0; 6,0)	4,0 (3,0; 5,0)	4,0 (2,0; 5,0)	3,0 (2,0; 3,0)	3,0 (1,0; 3,0)
-110 mmHg	4,0 (2,0; 6,0)	4,0 (4,0; 5,0)	4,0 (2,0; 7,0)	3,0 (1,0; 4,0)	2,0 (1,0; 3,0)	2,0 (0,0; 2,0)
-120 mmHg	10,0 (8,0; 14,0)*	10,0 (8,0; 12,0)*	8,0 (6,0; 9,0)*	8,0 (4,0; 9,0)*	4,0 (3,0; 6,0)	4,0 (2,0; 5,0)
-130 mmHg	10,0 (7,0; 15,0)*	10,0 (8,0; 14,0)*	10,0 (6,0; 13,0)*	10,0 (5,0; 12,0)*	10,0 (4,0; 11,0)*	10,0 (3,0; 11,0)*
-140 mmHg	6,0 (3,0; 8,0)	6,0 (5,0; 8,0)	6,0 (4,0; 7,0)	6,0 (3,0; 7,0)	4,0 (3,0; 5,0)	4,0 (2,0; 5,0)
-160 mmHg	6,0 (2,0; 7,0)	6,0 (5,0; 8,0)	6,0 (4,0; 7,0)	4,0 (2,0; 6,0)	4,0 (2,0; 6,0)	3,0 (1,0; 4,0)

*Note. * – p<0.001 according to the Wilcoxon test in comparison with a level at P=-100 mm Hg.*

x- is the duration of the negative pressure in minutes.

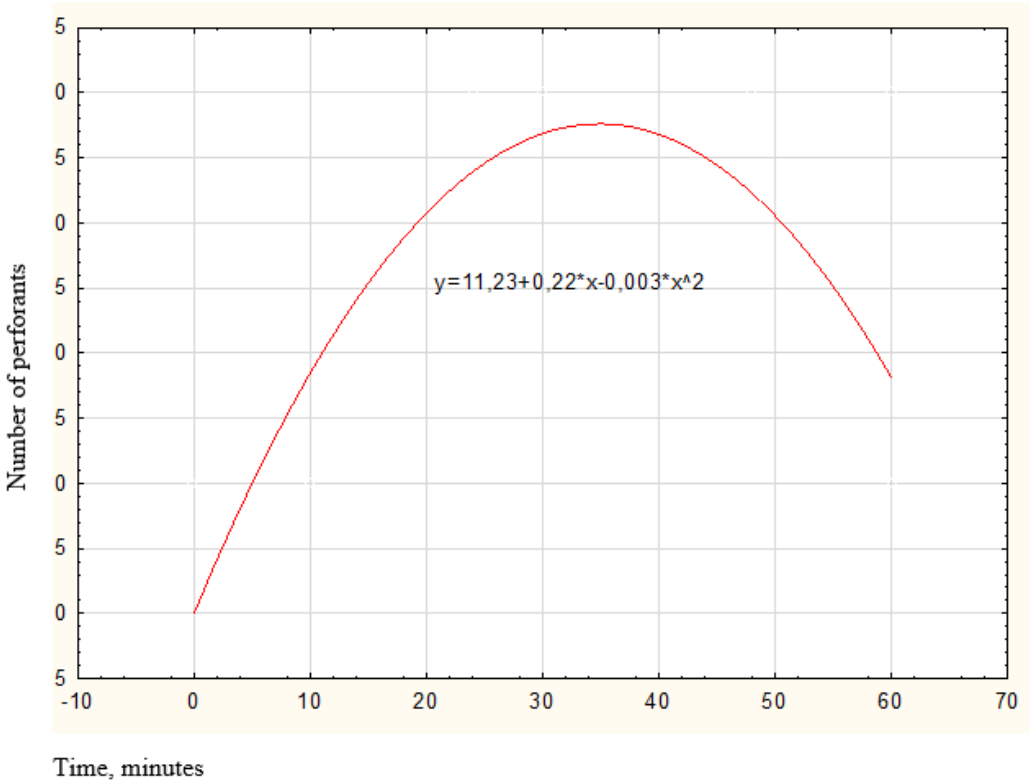

Fig.2. Relationship between the duration of negative pressure and the number of perforants in the examined GHV (n=35).

x- is the level of negative pressure in mm Hg.

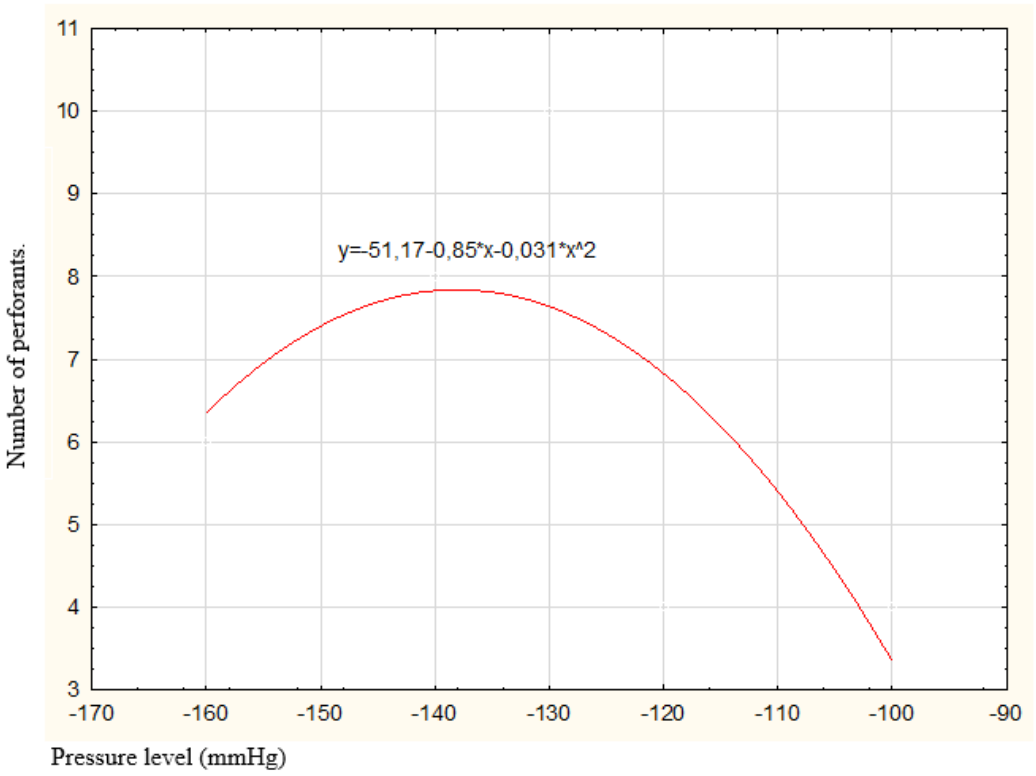

Fig.3. Relationship between the level of negative pressure and the number of perforants in the examined GHV (n=35).

thermal imager after using functional samples: cooling, heating, pressure. To create a uniform starting situation for the skin area, the use of cold or heat is recommended. The technique for applying cold has been described by de Weerd et al. [16]. The method was based on cooling the skin area to 20-22°C. After 60 seconds, hot spots appeared against the background of cooling. After 1-2 minutes, they merged with neighboring angiosome perforants. Thus, perforants up to 1 mm in diameter were visualized. Cooling ensures that only those areas that are best supplied with blood become noticeable hot spots a few minutes after the cold is removed [3-5,16]. Reducing the number of so-called "false hot spots" is critical to the accuracy of this method. Vacuum therapy is one of the treatments used to improve wound healing. The main pathogenetic mechanism of action of low-dose negative pressure is a change in local blood circulation, which is based on the ability of a local vacuum to create a directed movement of fluid, which provides optimal conditions for improving microcirculation [5,7,13]. In our opinion, the action of negative pressure is an important factor in enhancing blood flow in perforasomes, which contributes to an increase in dynamic zones due to the “opening” of perforants of the second and third levels.

Conclusion.

1. VAC-action promotes the opening of perforants of the second, third level and thereby improves the blood supply to the donor area.
2. Pressure P= (-130mm Hg) and time of 30 minutes are the most optimal modes of action on the skin of donor sites for opening perforants (10-12 pcs).
3. The use of local negative pressure against the background of cooling would be useful for training perforant vessels of the donor site during 2-3 days before the flap transplantation, which could reduce development of postoperative complications rate.

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PREOPERATIVE PREPARATION OF DONOR ZONES OF PERFORANT FLAPS BY THE METHOD OF TRAINING PERFORANT VESSELS WITH NEGATIVE PRESSURE

Trofimov N.[1] , Kryshen V.[1], Korpusenko I.[3], Nor N.[1], Korpusenko E.[1] , Makarenko A.[2]

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Summary. One of the key factors in achieving favorable treatment outcomes when planning reconstructive surgeries using perforant flaps is the choice of recipient vessels. Their

identification causes certain difficulties both at the planning stage and during the operation. The aim of the study was to develop the most rational modes of action of negative pressure on the skin of the thigh. For preoperative preparation of the donor zone for the formation of perforant flaps, a local vacuum (VAC - action) was used, which was created using a negative pressure apparatus "AGAT-Dnepr" (Ukraine) by applying it to the anterior surface of the thigh. Preoperative location of perforants was performed using a Flir ONE (USA) thermal imager for smartphones and tablets based on Android. The studies were carried out on a group of healthy volunteers - 35 people: 17 women and 18 men aged 19 to 50 years on the basis of the burn department of the clinic in Dnipro, Ukraine in 2020-21. at the same time at the specified time intervals - 60 seconds (immediately after the action of negative pressure); 20, 30, 60 minutes; after 24 and 48 hours. The highest average number of perforants in the examined patients was observed after 30 minutes of VAC- action - 12.0 (6.0; 12.0), which was statistically significantly higher compared to their number, which was detected after 10 minutes of negative pressure action ($p<0.001$). On average, according to the median values of 12 perforants after 30 minutes, the VAC action remained after 20, 30 and 60 minutes and decreased only after 24 hours. Doubling the period of VAC - action to 60 minutes and no longer led to an increase in the number of perforators. Therefore, the optimal negative pressure time was 30 minutes when up to 10-12 perforants are opened. The smallest average number of perforants was observed at the pressure level P=(-100 mmHg) 24 hours after the VAC-action and at P=(-160 mmHg) 48 hours later. The largest average number of perforants was detected at the pressure level P= (-130 mmHg) – 10.0 (8.0; 14.0), which was statistically significantly higher compared to their number under the negative impact of pressure P =(-100 mmHg) ($p<0.001$). The indicator was constant, the number of perforators was maintained during the entire observation period from 30 minutes to 48 hours. The action of local negative pressure contributed to the opening of perforants of the second and third levels and thus improved blood supply to the donor area. Pressure P= (-130 mm Hg) and time of 30 minutes was the most optimal mode of action on the skin of the anterior surface of the thigh, since 10 to 14 perforants were determined. The use of local negative pressure against the background of cooling may be useful for "training" the perforant vessels of the donor site for 2-3 days before surgery to reduce postoperative complications.

Keywords. Reconstructive surgery, negative pressure, perforant flaps, donor sites, dynamic thermography, blood flow.