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Skin microcirculation in healthy individuals measured with the use of laser Doppler flowmetry

Mikrokrążenie skórne mierzone laserową przepływometrią dopplerowską u osób zdrowych

Microcirculation is a part of circulatory system linking its arterial and venous part. Substantial functions of circulation, i.e. gas and metabolite exchange between blood and extravasal space as well as thermoregulation, are realized in this area. The total surface of the capillary vessels is estimated to be about 100 m^2 (averagely 600 capillaries per mm^3 of the tissue). At rest only 25% of them are active. The microcirculation net is not homogenous, in metabolically active organs it is dense and poorly innervated, regulated by substances produced in the epithelium – vasodilating (mainly NO and prostacycline) or vasoconstrictive (EDCF1, EDCF2). The skin microcirculation is regulated mainly by neurogenic factors.

The evaluation of the microcirculation is difficult because of its complex, heterogeneous structure, microscopic size of the vessels, and low but changing velocity of the blood cells flow. The measurements are performed using the Xe clearance, dynamic capillaroscopy, pletysmography, thermoelectric methods and ultrasound examinations. Recently the most popular method becomes the laser Doppler flowmetry (LDF). A beam of neon-helium laser light is distracted by immobile elements of the tissue, while it is reflected by mobile elements of the blood – especially erythrocytes – thus changing its frequency. The range of the frequency changes depends upon the velocity of the red cells' movement and the indication of the laser Doppler gauge is positively correlated with the mean erythrocytes concentration and their mean velocity ratio in the penetrated tissue. The reflected and dispersed radiation is registered and processed by the computer using the Perimed program [6,8,12]. The laser Doppler technique is applied in the diagnosis of the peripheral vessels diseases. The method is noninvasive, reproducible, not stressing the patient, doesn't disturb his circulation, allows constant measurements and small size of the probes allows measurements in various places of the skin. The technique of the measurements is quite easy, but the interpretation of the results seems difficult. The "normal" range of perfusion values has not been established yet. Therefore, the method of percent evaluation of flow change after provocation tests is more reliable. The most often performed tests are hyperemic tests after occlusion or thermal stimulus (warm or cold), orthostatic test and Valsalva test. The standard measurement places are not determined too. The probe is most commonly placed on the dorsal side of the foot, on internal side of the forearm or on the back of the hand.

The authors of the study tried to standardize the evaluated parameters with the measurements performed with the probe placed on the dorsal side of the hand, between I and II metacarpal bones.

MATERIAL AND METHODS

The study included 92 healthy, non-smokers volunteers, aged 19 to 39 years, (mean age of 21,92±2,91). The participants were asked not to take part in physical activities and to avoid products that influence the circulation (alcohol, coffee, tea and Coca-Cola).

The tests were performed in horizontal position on the back, in a constant temperature of 21±1,2°C, after ca. 20 minutes of adaptation. The microcirculation was evaluated with the use of a laser Doppler flowmeter (Perifluks 4001, Perimed, Sweden), which generates laser light of 632,8 μm wave length (red light). The optode was placed on the skin of the back of the hand between the first and second metacarpal bones using special both sides adhesing ring. The flow was measured in conventional Perfusion Units score (PU), in proportion to the energy of the Doppler signal. 1PU corresponds to 10 mV at the outlet.

The course of the experiment:

1. The procedure was started after 20 minutes of stabilization of the circulatory system in horizontal position.
2. Blood pressure (RR) measurement (mmHg) – on the brachial artery.
3. Registration of the rest flow (RF) in horizontal position, on a dominating upper limb, registration time 2 min.
4. Registration of the flow after occluding the arm with the cuff of the manometer filled with air up to pressure exceeding the formerly measured systolic pressure by 50 mmHg, biological zero (BZ) - registration time 2 min.
5. Registration of the reactive hyperemia (RH) after loosening the cuff, registration time 2 min. Stabilization of the blood flow back to rest flow level.
6. Stabilization of the blood flow back to rest flow level.
7. Rising the optode's temperature up to 44°C, using the built-in heating module, 1 min.
8. Registration of the thermal hyperemia (TH), registration time 2 min.

The values of the parameters are presented as median ± standard deviation (SD).

RESULTS

The results are presented in table 1.

Tab. 1 Chosen parameters of the microcirculation in tested group (PU)

Parameter	Median (PU)	Maximum (PU)	Minimum (PU)
RF	12,73±6,25	31,81	3,68
BZ	3,48±0,83	6,45	2,26
RH	54,2±35,13	240	14,04
TH	169,76±84,29	468,12	58,5

RF – rest flow in horizontal position.
BZ – biological zero.
RH – mean flow during post-occlusive hyperemic reaction.
TH – median value of the flow during thermal hyperemia.

DISCUSSION

The blood flow in the vascular bed is very variable due to extrinsic and intrinsic factors. Former studies evaluating laser Doppler flowmetry report various values depending upon the measurement place. Low perfusion values are noted on lower limbs and the corpse, higher – on upper limbs. The most intensive perfusion was noted on lips, then on chin, nose, forehead and cheeks. The worst blood flow was observed on breech as well as on dorsal and plantar side of the foot [12]. The correlation of perfusion and temperature is unquestionable. The blood flow in 20 – 25˚C remains stable, below 17˚C

the flow values decrease and above 30˚C increase significantly [2]. Grodzicki et al. (2003) reports 38˚C as the upper limit for the stabile flow [6].

The perfusion changes are triggered by physical exercise and sportsmen present with higher flow values at rest [6,15]. Other authors registered momentary changes in blood flow during exercise [9,10,14]. Reports concerning the correlation between microcirculation and gender are equivocal. Huether et al. (1986) and Agner (1991) found no differences in perfusion in men and women, whereas De Boer et al. (1989), Stucker et al. (2001) and Szyguła et al. (2004) have shown higher blood flows in men. No correlation with the age has been found [2,6,12,16]. In healthy individuals, after occlusive or thermal stimulation, the increased reactivity of the vessels occurred together with decreased rest flows [7].

In presented study the authors tried to eliminate the influence of most external factors, the tests were performed in comparable, standardized conditions, on nonsmokers, excluding circulation affecting condiments and with probes placed on dominant limb. The volunteers were young and healthy. It should be noted that the test group included individuals of both sexes (24 women and 68 men), but despite the controversies about differences in microcirculation in men and women, it is commonly assumed that they are rather small [2]. The rest perfusion on the dorsal side of the dominating hand was 12,73±6,25 PU, which corresponds with the few existing reports from the literature. Żygocki et al. noted hand flows at the level 12,13±5,65 PU. Buraczewska et al. suggest that the flow should be between 10 – 20 PU, but that's a very wide norm, which should be narrowed and related to the measurement place [3]. Other authors note that the perfusion is better [4,8,17] or worse [3,11] in persons with endothelial diseases compared to healthy ones.

Hyperemic reaction after occlusion is based upon myogenic reaction of the vessels to the increased transmural pressure after opening of the arteries. It is known from the literature that the post-occlusive blood flow should be increased by 400 – 600%, which was confirmed by the present study – the increase reached 425% compared to rest values. Mean flow values after occlusion were 54,2±35,13 PU. In persons with impaired peripheral circulation the hyperemic reaction is significantly lower [3,4,8,17]. The increase in skin's temperature leads to remarkable increase of perfusion due to opening of the arterioles, retracted capillaries and anastomoses. The blood flow should increase by several times compared to rest conditions, when not – it proves impaired myogenic reaction of the vessels. In the tested group the flow after heating rose over 13 times.

The index of percent changes of flow during provoked hyperemic reactions is very useful but standardization of the perfusion normal values range would enhance the early diagnosis of the peripheral circulation. The epithelium is the place of the earliest manifestations of such diseases as diabetes, arterial hypertension and the ischemic disease. Functional lesions appear in the early stages of the disease significantly ahead of the structural changes.

Mean values of the blood flow in the presented study, both in resting conditions and after stimulation, did not exceed the ranges reported in literature, nevertheless it should be noted that former studies were performed with the probe placed on foot or forearm. The significant dispersion of the obtained values makes the author cautious in formulating final conclusions concerning standard values.

For these reasons this report should be regarded as preliminary and requiring further studies.

CONCLUSIONS

1. The essential reactivity of the microcirculation to external and internal stimuli makes it difficult to interpret the obtained values of perfusion. Further studies are necessary to standardize the optimal measurement places and to define normal ranges of blood flow.
2. The obtained values of blood flow and hyperemic reactions on the dorsal side of the hand locate in the ranges given in literature, which confirms that the back of the hand is a good and comfortable measurement place.
3. The obtained mean values should be regarded as preliminary and requiring further confirming studies.

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ABSTRACT

The interpretation of the results with the use of laser Doppler flowmetry. Seems difficult. The "normal" range of perfusion values has not been established yet. The authors of the study tried to standardize the evaluated parameters with the measurements performed with the probe placed on the dorsal side of the hand, between I and II metacarpal bones. The obtained values of blood flow and hyperemic reactions on the dorsal side of the hand locate in the ranges given in literature, which confirms that the back of the hand is a good and comfortable measurement place. The obtained mean values should be regarded as preliminary and requiring further confirming studies.

STRESZCZENIE

Inerpretacja wyników uzyskanych w pomiarach laserową przepływometrią dopplerowską jest zagadnieniem trudnym. Nie ustalono przedziału wartości perfuzji, które można by uznać za normę. Celem niniejszej pracy jest próba standaryzacji ocenianych parametrów przy punkcie pomiarowym umieszczonym na grzbiecie ręki, pomiędzy I a II kością śródręcza. Badaniami objęto 92 zdrowych ochotników. Badania mikrokrążenia dokonano laserowym przepływomierzem Dopplerowskim Perifluks 4001 firmy Perimed (Szwecja). Optoda została umieszczona na skórze grzbietu ręki dominującej, pomiędzy I a II kością śródręcza. Uzyskane wyniki wyznaczyły średnie wartości przepływu podstawowego, pookluzyjnej reakcji przekrwiennej, reakcji w odpowiedzi na bodziec termiczny, jednak wymagają one potwierdzenia w dalszych badaniach.