

The state of microcirculation in the lower extremities in patients with sepsis complicated by complicated diabetic foot syndrome

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Abstract

Objective. To study lower limb blood flow parameters in patients with sepsis against the background of complicated diabetic foot syndrome using laser Doppler flowmetry.

Materials and Methods. A total of 126 patients with sepsis caused by complicated diabetic foot syndrome were examined. All patients were treated at the city purulent-septic center with “diabetic foot beds” at Zaporizhzhia City Hospital No. 4 between 2005 and 2025. The cause of sepsis in 115 (91.3%) patients was “wet” gangrene of the lower extremities. In the remaining 11 (8.7%) patients, sepsis developed due to phlegmon and widespread osteomyelitis of the foot. All patients underwent surgery under general anesthesia. Additionally, a control group of 18 healthy individuals was formed for participation in the study. Microcirculation was assessed using laser Doppler flowmetry with the LAKK-02 analyzer (LAZMA Scientific and Production Enterprise LLC).

Results. In patients with sepsis complicated by diabetic foot syndrome, the mean blood flow rate—as a constant component of blood circulation—was (9.23 ± 0.54) perfusion units, which was three times higher than the corresponding control value; this difference was statistically significant ($p < 0.05$). The increase in the mean perfusion index indicated an increase in blood volume in the arterioles and venules. The mean perfusion fluctuation index, as a variable component of blood circulation, was (1.4 ± 0.22) perfusion units and was 2 times higher than the control values ($p < 0.05$). This indicated increased modulation of blood circulation and more intensive functioning of the mechanisms of active microcirculation control. The coefficient of variation was $(17.65 \pm 1.69)\%$ and was 2 times lower than control values, with a statistically significant difference ($p < 0.05$). This reflected a deterioration in microcirculation.

Conclusions. The use of laser Doppler flowmetry in patients with sepsis against the background of complicated diabetic foot syndrome allows for obtaining reliable data on the state of the microcirculatory bed of the lower extremities.

Keywords: sepsis; complicated diabetic foot syndrome; microcirculation.

The challenge of treating sepsis remains as relevant and pressing as ever, even at this stage of medical advancement, as incidence rates are rising and mortality rates remain high. According to data from the Global Sepsis Alliance, sepsis is one of the most common yet least frequently diagnosed complications in healthcare facilities. Annually, the incidence of sepsis worldwide increases by 8–13%, requiring enormous financial resources for the treatment of patients in this category [1, 2].

National healthcare systems in every country without exception consider the treatment of diabetes and its complications a priority. This is due not only to the fact that the number of patients is steadily increasing, but also to the high frequency of complications that lead to disability and death [3–5].

It is quite difficult to diagnose and treat diabetic foot syndrome. The number of patients with complicated diabetic foot syndrome increases by 2–6% each year [4, 6].

The development of this condition is significantly influenced by lower extremity angiopathy due to a reduction in

vessel diameter, blood flow velocity, and deterioration of blood rheological properties [4, 7].

The microcirculatory bed plays a key role in maintaining the necessary level of metabolism in tissues. Thanks to the microcirculatory bed—composed of arterioles, capillaries, arteriovenous anastomoses, and venules—nutrients, oxygen, and medications are delivered to the tissues.

Among combined therapeutic and surgical conditions, the course of purulent surgical infection against the background of chronic systemic disease deserves special attention, which explains the relevance of this study [4].

Study objective: to investigate lower extremity blood flow parameters in patients with sepsis against the background of complicated diabetic foot syndrome using laser Doppler flowmetry.

Materials and methods

A total of 126 patients with sepsis against the background of complicated diabetic foot syndrome were examined; these patients were treated at the purulent-septic center with “dia-

betic foot beds” at Zaporizhzhia City Clinical Hospital No. 4 from 2005 to 2025.

The average duration of type 2 diabetes was (12.7 ± 2.7) years. The average age of the patients was (63.2 ± 2.3) years. Comorbidities included diseases of the cardiovascular and respiratory systems. Additionally, a control group consisting of 18 healthy men and women (equal numbers of each) was formed for participation in the study.

Microcirculation was studied using the LAKK–02 analyzer (LAZMA Scientific and Production Enterprise LLC) via laser Doppler flowmetry. Skin blood flow parameters were measured at rest. The sensor was placed on the dorsal surface of the foot in the first interdigital space.

Microcirculatory parameters were recorded with the patient in a horizontal position for 10 minutes, followed by processing of the obtained data.

We calculated the values of mean perfusion fluctuation, mean blood flow, and the coefficient of variation, which was defined as the ratio of mean blood flow to mean perfusion fluctuation. We recorded the oscillatory process caused by active (endothelial, neurogenic, myogenic) and passive (cardiac, respiratory) factors. We also calculated neurogenic and myogenic tones and the shunting index.

Statistical analysis of the obtained data was performed using the STATGRAPHICS Plus for Windows 7.0 software package.

The statistical significance of differences between compared variables with a normal distribution, as determined by the Kolmogorov–Smirnov test, was assessed using Student’s *t*-test for means and Fisher’s *F*- ; a *p*-value of ≤ 0.05 was

considered statistically significant. The analyzed data are presented as mean \pm standard deviation (*M* \pm *SD*).

Results

Severe ischemia of the lower extremities in patients with sepsis is caused by hemodynamic disturbances combined with suppression of tissue metabolism.

Basal blood flow parameters in patients with sepsis were calculated in stages (*see table*). Initially, the mean values of perfusion changes were determined. In sepsis, the mean blood flow (constant component of blood flow) was (9.23 ± 0.54) perfusion units and exceeded control values by a factor of 3; the difference was statistically significant ($p < 0.05$). The mean perfusion variation index (the variable component of blood flow) was (1.4 ± 0.22) perfusion units, which was 2 times higher than the control values ($p < 0.05$).

The coefficient of variation was $(17.65 \pm 1.69)\%$ and was 2 times lower than the control values, with a statistically significant difference ($p < 0.05$).

The amplitude of endothelial oscillations (active factor) did not exceed the control value by much and amounted to (0.62 ± 0.17) perfusion units; however, the difference was statistically significant ($p < 0.05$).

The amplitude of neurogenic oscillations (active factor) was statistically significantly ($p < 0.05$) higher than the control values and amounted to (0.61 ± 0.05) perfusion units.

The amplitude of myogenic oscillations (active factor) was slightly higher than the control values and amounted to (0.49 ± 0.03) perfusion units ($p < 0.05$).

Microcirculation parameters in patients with sepsis against a background of complicated diabetic foot syndrome (*M* \pm *m*)

Indicators	Indicator values		p
	Control (n = 18)	Patients with sepsis	
Mean blood flow, ml/min	2.6 \pm 0.22	9.23 \pm 0.54	0.019
Mean perfusion variation, perf. units	0.87 \pm 0.1	1.4 \pm 0.22	0.031
Coefficient of variation, %	39.89 \pm 3.9	17.65 \pm 1.69	0.025
Amplitude of oscillations, pF			
endothelial	0.47 \pm 0.03	0.62 \pm 0.17	0.040
neurogenic	0.49 \pm 0.04	0.61 \pm 0.05	0.039
myogenic	0.39 \pm 0.07	0.49 \pm 0.03	0.045
pulse wave	0.13 \pm 0.02	0.12 \pm 0.02	0.057
respiratory wave	0.19 \pm 0.03	0.27 \pm 0.31	0.035
Tone, pF/unit			
neurogenic	2.2 \pm 0.02	2.8 \pm 0.21	0.058
myogenic	2.8 \pm 0.30	3.4 \pm 0.19	0.030
Shunt index, pF units	1.4 \pm 0.04	1.32 \pm 0.09	0.047
Note.	PU – perfusion units.		

Changes in the amplitude of the pulse wave (passive factor) relative to the control value were statistically significant ($p > 0.05$).

The amplitude of the respiratory wave (passive factor) was (0.27 ± 0.31) perfusion units and was statistically significantly ($p < 0.05$) higher than the control values.

Neurogenic tone was slightly elevated and amounted to (2.8 ± 0.21) perfusion units ($p < 0.05$).

An increase in the myogenic tone of precapillaries to (3.4 ± 0.19) perfusion units was also determined ($p < 0.05$).

The shunt index in sepsis decreased to (1.32 ± 0.09) perfusion units.

Discussion

An increase in mean blood flow reflects an increase in blood volume in arterioles and venules and indicates enhanced blood flow modulation and more intensive functioning of the mechanisms of active microcirculation control.

Coefficients of variation, which are 2 times lower than control values, reflect impaired microcirculation.

Endothelial regulation of the precapillary bed is ensured by the production of nitric oxide. Endothelial dysfunction may be due to a change in the response to nitric oxide production or a faster rate of its inactivation.

An increase in the amplitude of neurogenic oscillations is associated with the activation of sympathetic vasomotor fibers and leads to an increase in arteriolar tone.

The amplitude of myogenic oscillations is used to assess the muscle tone of precapillaries, which regulates blood flow to the nutritive bed.

If an increase in the amplitude of the respiratory wave is detected, it indicates impaired blood outflow from the microcirculatory bed and an increase in blood volume in the venules. A simultaneous increase in the microcirculation index and the amplitude of the respiratory wave indicates stasis in the microcirculatory bed.

Neurogenic tone increases in response to increased activity of the sympathetic nervous system. An increase in myogenic tone of precapillaries during sepsis affects arteriolar constriction, reducing their diameter.

The shunting index decreases in sepsis due to changes in the regulation of arteriovenous anastomoses and arterioles, which promotes blood redistribution toward the nutritive circulation.

Pulse wave amplitude is used to assess the preservation of vascular elasticity and the necessary volume of arterial blood relative to the volume of the microcirculatory bed.

Conclusions

1. The use of laser Doppler flowmetry in patients with sepsis complicated by diabetic foot syndrome allows for the collection of reliable data on the condition of the microcirculatory bed.

2. In sepsis, due to stasis in arterioles and venules, the mean blood flow and mean perfusion fluctuation indices increase significantly.

3. In patients with sepsis, significant changes occur in the active and passive factors of lower limb microcirculation.

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