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# *Characteristic features of hemodynamics in the femoral neck of children with femoral head aseptic necrosis*

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**Purpose** To study the characteristic features of femoral neck blood circulation in children with femoral head ischemic defects of traumatic and dysplastic genesis. **Materials and methods** The authors analyzed rheovasography results of 17 patients with the ischemic femoral head defects developed due to posttraumatic aseptic necrosis (Group 1, n=9) and Legg-Calve-Perthes disease (Group 2, n=8). The measurements were performed before surgery, after tunnel perforation of the neck, and after cell-and-tissue transplantation. **Results** More marked changes in the parameters of pulse blood filling were recorded in Group 2 and corresponded to the state of decompensation ischemia that might be associated with the disorders of venous blood outflow. **Conclusion** The results confirm the feasibility of re-interventions that stimulate hemodynamics and the use of a prolonged stimulation with wires in order to achieve the draining effect.
**Keywords**: Legg-Calve-Perthes disease (LCPD), posttraumatic aseptic necrosis, rheovasography

## INTRODUCTION

Avascular necrosis is one of the main causes of femoral head deformity and defect in children. Local hemodynamic disorders that may result from arterial flow cessation, venous stasis, thrombosis or bone marrow edema are the leading causes in its pathogenesis [12]. Several factors may be responsible for development of ischemia. Damage to vessels and blood inflow disorders are the main factors in posttraumatic necrosis. The mechanism of non-traumatic necrosis is more complex. Thus, in Legg-Calve-Perthes disease it may include intravascular thrombosis due to thrombophillia, venous stasis and bone marrow edema that is associated with the stasis [11]. The possibilities of joint salvage surgeries in cases of a marked collapse and fragmentation of the femoral head are considerably reduced. The interventions acquire a palliative character and are directed to the improvement of joint relationships, joint function and femoral head structure. Various variants of osseoperforation, implantation of bone marrow stem and stromal cells are used for stimulation of reparative processes [9, 10]. Several authors advocate the use of external fixation for improving joint relationship [3, 7, 8].

The surgeons of the RISC for RTO use the technique that includes joint decompression with the apparatus, femoral neck and head perforation and cell-and-tissue transplantation (injection of 1.5 to 2 ml of the puncture aspiration material harvested from the iliac wing) into the perforated tunnels [5]. As far as this technique implies introduction of wires into the femoral neck and head, it was decided to use them as electrodes for evaluation of blood flow in the femoral neck by recording electrical impedance (rheovasography) [1, 2].

**Purpose** To study blood circulation features in the femoral neck in children with femoral head ischemic defects of traumatic or dysplastic genesis.

## MATERIAL AND METHODS

Results of using rheovasography in 17 patients with femoral head ischemic defects were analyzed. Inclusion criteria were the age older than 6 years, etiological factors (injury or Legg-Calve-Perthes disease), and the size of a femoral head defect not less than 30 % that developed due to necrosis. Exclusion criteria were the age younger than 6 years, aseptic necrosis due to septic arthritis associated with medical preparations or autoimmune diseases, and femoral head defect size less than 30 %. The selected patients were divided into two groups. Group 1 included nine children (4 boys and 5 girls) that had posttraumatic aseptic necrosis of the femoral head. Among them, the pathological condition developed due to a femoral neck fracture in seven cases. It was caused by traumatic hip dislocation in the other two. The time between the injury and examination ranged from four to 7 months. Their mean age was 10.5±0.9 years (range: 8-13 years). The affected joints corresponded to grade IV C (impression more than 30 %) according to ARCO classification [11].

Group 2 were eight patients with grade III Legg-Calve-Perthes disease. The duration of the disease was from six to 10 months. Their mean age was 9.4±0.4 years (range: 8–11 years). There were six boys. According to the Catterall's classification, five joints were of class III and three joints of class IV. Herring grading of joints was two cases of B/C type and six were of C type.

Bipolar rheovasography was used to study the changes in blood supply.

The study was conducted before the operation. The patients lay supine under general anesthesia. Wires of 1.8 mm in diameter served as electrodes. The first wire

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was inserted from the lateral side along the femoral neck axis up to the proximal growth zone. The second wire was drilled into the femoral head from the anterior surface. The wire that passed through the femoral epiphysis served as a common electrode.

Impedance of the intramedullary tissues was recorded with the first and second wire. The third wire for recording the impedance of the paraosseus tissues was inserted at a 1-cm distance from the first one into the soft tissues till it stopped moving. Electrodes were the second and third wires.

RGPA-6/12 «REAN-POLY» polyanalizer (Medicom-MTD, Taganrog) was used in the study. Frequency of probe current was 56 kHz. Electrocardiogram in II standard indirect leads, impedance, rheovasograms of intramedullary (RVGi) and paraosseous (RVGp) tissues and their derivatives were recorded simultaneously. Exit of the parameters of the pulse wave in the numerical expression with regard to calibration signal was provided with the polyanalizer.

Parameters that characterize the tone of vessel walls (pulse wave distribution time, index of vessel tone (IVT), index of peripheral vascular resistance (IPVR), index of vessel elasticity), pulse blood filling (amplitude of rapid blood filling, rheographic index, relative volumetric pulse) and venous outflow (index of venous outflow, dectrotic vascular index, amplitude of the systolic phase of the venous components) were chosen for the quantitative analysis (**Table 1**) [4]. Duration of pulse wave (RR, sec) was determined basing on the distance between the tooth R of ECG. Volumetric blood flow velocity was calculated according to the formula:

$Vq100 = (135 \times 60 \times tg\ a \times Tiz. \times k) / (RR \times BI \times Ac)$, ml/min per 100 $cm^3$ of tissues where *135* is the specific blood flow resistance, V m/$cm^3$; *60* – number of seconds; *tg a* – amplitude/time of rapid blood filling, V m/sec; *Tiz* – ejection period according to Karpman = $0.109 \times (RR + 0.159)$, sec. Relative volumetric pulse RVP = PI × 1000 / BI × RR, permille was calculated for comparing the intensity of blood filling.

Tunnel perforation in the femoral neck was performed upon completion of recording of the parameters mentioned that characterize blood circulation in the area of the growth zone. Six wires were introduced parallel to the first wire and immediately removed. Blood flow study was repeated.

One milliliter of autologous blood that contained elements of bone marrow was then injected into one of the perforated tunnels with a long needle and a syringe. The harvesting of the autologous material from the iliac wing was performed immediately before injection. Blood flow study was re-recorded.

The parameters of the pulse wave changed unidirectional in all the patients. Therefore, a small number of cases from each of the groups was used for drawing the conclusions on the direction of blood flow changes. Thus, it was possible to refer the values of significant difference to the changes in the others by the analysis of hemodynamic situations. AtteStat software (I.P. Gaidyshev, application to Excel) was used to calculate the theoretical frequencies of the normal curve. Kolmagorov-Smirnov criterion was used to confirm the coincidence of the empirical frequencies with the theoretical ones. Then, the arithmetical average and its error were defined. Significance of differences between the mean values was determined using the paired Student's t-test.

The study was conducted in accordance with the ethical standards of the Helsinki declaration of the World Health Organization and amendments of the RF ministry of health. Informed consents were given by the legitimate representatives of the patients included into the study.

## RESULTS

The distance between the wire inserted into the femoral head and the femoral neck surface was ~1 cm, and between the wire in the epiphysis and the third wire in the paraosseous tissues was ~ 6.0 cm. The ratio of the distance between the electrodes was 1:6.

Basic impedance of paraosseous tissues (BIp) was 154 % in the first group and 156 % in the second group from the basic impedance of intramedullary tissues (BIi), respectively.

Control studies did not revealed statistically significant differences between BIi as well as between the parameters of blood flow of the patients in group 1 and group 2. The values of vessel wall tone were higher in both groups (**Table 1**, **lines 6-8**) while the indices of pulsed blood filling were lower (**Table 1, lines 13, 14**) than the average statistical values. Moreover, patients of group 2 showed a lower time of the pulse wave distribution (TPWD) – 92 %, rheographic index (RI) – 45 %, relative volumetric pulse (RVP) – 33 %, average velocity of slow blood filling of pulse wave (AVSBF) – 62 %, volumetric velocity of blood flow (Vq100) – 76 % and index of the venous outflow (IVO) – 66 %.

After the tunnel perforation of the femoral neck in the patients of group 1, the statistically significant changes were the index of peripheral vascular resistance that reflects the tone of resistive vessels (IPVR) – 125 % ($p < 0.05$) and the index of venous outflow (IVO) – 202 % ($p < 0.05$). The rheographic index (RI) and the relative volumetric pulse (RVP) decreased more expressively, by 52 and 47 % respectively. Maximum velocity of fast blood filling (MVFBF) – 143 % and volumetric velocity of blood flow (Vq100) – 153 % (table 2) increased.

Upon the injection of the autologous blood into the perforation tunnels, the index of regional middle caliber arteries elasticity (IEM) – 75 % ($p < 0.05$) and the time of the maximum systolic pulse wave filling (TMSF) – 86 % ($p < 0.05$) decreased statistically significantly but MVFBF increased – 156 % ($p < 0.05$) in group 1. IPVR, IVO and Vq100 recovered by the increase of AVSBF and decrease of the amplitude parameters of pulse blood filling (table 2).

**Table 1**

Parameters of blood flow in the femoral neck in groups 1 and 2

| N | Parameters | Mean statistic range | Group 1, n = 9 (100 %) | Group 2, n = 8 | % | p < |
|---|---|---|---|---|---|---|
| 1 | BIi, Om | – | 48.9 ± 7.2 | 48.6 ± 5.9 | 99 | – |
| 2 | BIp, Om | – | 75.4 ± 8.0 | 75.6 ± 8.5 | 100 | – |
| 3 | BIi 1, $BIp_1$ | | 48.9 ± 7.2 | 75.4 ± 8.0 | 154 | 0.05 |
| 4 | BIi 2, $BIp_2$ | | 48.6 ± 5.9 | 75.6 ± 8.5 | 156 | 0.05 |
| 5 | TPWD, sec | 0.18–0.21 | 0.200 ± 0.013 | 0.183 ± 0.006 | 92 | – |
| 6 | IVT, % | 10–15 | 19.1 ± 1.0 | 20.2 ± 1.2 | 106 | – |
| 7 | IEM, % | 40–100 | 125.6 ± 9.6 | 129.9 ± 10.9 | 103 | – |
| 8 | IPVR, % | 20–45 | 81.1 ± 6.4 | 87.4 ± 2.0 | 108 | – |
| 9 | MVFBF, Om/sec | 1.16–1.86 | 0.244 ± 0.035 | 0.220 ± 0.036 | 90 | – |
| 10 | AVSBF, Om/sec | 0.22–1.6 | 0.241 ± 0.042 | 0.149 ± 0.029 | 62 | – |
| 11 | TFBF, sec | 0.06–0.08 | 0.050 ± 0.002 | 0.054 ± 0.003 | 108 | – |
| 12 | TSBF, sec | 0.04–0.06 | 0.056 ± 0.004 | 0.054 ± 0.003 | 94 | – |
| 13 | TMSF, c | 0.11–0.13 | 0.106 ± 0.005 | 0.108 ± 0.002 | 102 | – |
| 14 | AFBF, Om | – | 0.0068 ± 0.0008 | 0.0062 ± 0.0010 | 91 | – |
| 15 | RI, Om | Higher than 0.5 | 0.0361 ± 0.0095 | 0.0164 ± 0.0030 | 45 | – |
| 16 | RVP, promille | 0.5–0.8 | 0.1894 ± 0.0644 | 0.0622 ± 0.0085 | 33 | – |
| 17 | Vq100, ml/min в 100 $cm^3$ of tissue | 1.9–4.7 | 4.468 ± 0.630 | 3.877 ± 0.448 | 87 | – |
| 18 | IVO, % | 20-50 | 20.8 ± 3.2 | 13.7 ± 2.3 | 66 | – |
| 19 | DVI, % | – | 49.8 ± 2.9 | 47.1 ± 5.3 | 95 | – |
| 20 | ASPVC, mOm | – | 0.0136 ± 0.0025 | 0.0156 ± 0.0030 | 115 | – |

Note: 1 – group 1, 2 – group 2

**Table 2**

Changes in parameters of blood flow in the femoral neck after tunnel perforation with wires and cell-tissue transplantation in group 1

| N | Parameters | Tunnel perforation | % | p < | Autologous blood | % | p < |
|---|---|---|---|---|---|---|---|
| 1 | BIi, Ом | 49.7 ± 12.5 | 102 | – | 54.1 ± 20.2 | 111 | – |
| 2 | BIp, Ом | 80.0 ± 17.9 | 106 | – | 65.3 ± 13.7 | 87 | – |
| 3 | BIi / BIp, % | | 154 | 0.05 | | 121 | – |
| 4 | TPWD, sec | 0.197 ± 0.013 | 99 | – | 0.174 ± 0.021 | 87 | – |
| 5 | IVT, % | 19.5 ± 7.8 | 102 | – | 16.9 ± 1.3 | 88 | – |
| 6 | IEM, % | 114.3 ± 7.4 | 91 | – | 94.4 ± 5.4 | 75 | 0.05 |
| 7 | IPVR, % | 101.1 ± 6.0 | 125 | 0.05 | 75.8 ± 15.5 | 93 | – |
| 8 | MVFBF, Om/sec | 0.350 ± 0.096 | 143 | – | 0.381 ± 0.050 | 156 | 0,05 |
| 9 | AVSBF, Om/sec | 0.211 ± 0.063 | 88 | – | 0.300 ± 0.139 | 124 | – |
| 10 | TFBF, sec | 0.048 ± 0.001 | 96 | – | 0.047 ± 0.001 | 94 | – |
| 11 | VSBF, sec | 0.054 ± 0.004 | 96 | – | 0.044 ± 0.003 | 79 | – |
| 12 | TMSF, sec | 0.103 ± 0.005 | 97 | – | 0.091 ± 0.003 | 86 | 0.05 |
| 13 | AFBF, Om | 0.0078 ± 0.0012 | 115 | – | 0.0074 ± 0.0030 | 109 | – |
| 14 | RI, Om | 0.0187 ± 0.0054 | 52 | – | 0.0271 ± 0.0101 | 75 | – |
| 15 | RVP, promille | 0.0893 ± 0.0375 | 47 | – | 0.1124 ± 0.0541 | 59 | – |
| 16 | Vq100, ml/min in 100 $cm^3$ of tissue | 6.780 ± 1.319 | 152 | – | 4.708 ± 1.186 | 105 | – |
| 17 | IVO, % | 42.0 ± 8.0 | 202 | 0.05 | 21.0 ± 7.8 | 101 | – |
| 18 | DVI, % | 61.7 ± 10.2 | 124 | – | 56.2 ± 10.1 | 113 | – |
| 19 | ASPVC, mOm | 0.0119 ± 0.0030 | 88 | – | 0.0116 ± 0.0075 | 85 | – |

Upon tunnel perforation, a statistically significant decrease in BI by 53 % ($p < 0.05$), RI by 33 % ($p < 0.05$), maximum velocity of fast blood filling (MVFBF) by 36 % ($p < 0.05$), average velocity of slow blood filling (AVSBF) by 35 % ($p < 0.05$), and amplitude of the systolic phase of the venous component (ASPVC) by 35 % ($p < 0.05$) was revealed in group 2. The increase of IVO by 239 % ($p < 0.05$), Vq100 by 140 % (p < 0.05, IPVR by 119 % was observed (**Table 3**).

After cell-and-tissue transplantation, a statistically significant reduction in BI by 58 % ($p < 0.05$), RI by 40 % ($p < 0.05$) and MVFBF by 36 % ($p < 0.05$) were preserved in children of group 2. Reduction in the AVSBF by 43 % and ASPVC by 54 %, as well as the increase in IVO by 126 % and Vq100 by 130 % were also preserved. Increase in IPVR made 103 %, and the IEM reduced down to 83 % (**Table 3**).

**Table 3**

Changes in parameters of blood flow in the femoral neck after tunnel perforation with wires and cell-tissue transplantation in group 2

| N | Parameters | Tunnel perforation | % | p < | Autologous blood | % | p < |
|---|---|---|---|---|---|---|---|
| 1 | BIi, Om | 26.0 ± 5.1 | 53 | 0.05 | 28.0 ± 4.8 | 58 | 0.05 |
| 2 | BIp, Om | 51.6 ± 5.7 | 68 | 0.05 | 56.4 ± 6.7 | 75 | – |
| 3 | BIi, BIp | | 198 | 0.05 | | 201 | 0.05 |
| 4 | TDPV, sec | 0.178 ± 0.009 | 97 | – | 0.172 ± 0.007 | 94 | – |
| 5 | IVT, % | 17.7 ± 1.9 | 88 | – | 18.3 ± 2.4 | 91 | – |
| 6 | IEM, % | 103.2 ± 11.6 | 79 | – | 108.4 ± 14.6 | 83 | – |
| 7 | IPVR, % | 103.6 ± 9.9 | 119 | – | 89.6 ± 9.5 | 103 | – |
| 8 | MVFBF, Om/sec | 0.080 ± 0.029 | 36 | 0.05 | 0.100 ± 0.031 | 45 | 0.05 |
| 9 | AVSBF, O m/sec | 0.052 ± 0.024 | 35 | 0.05 | 0.064 ± 0.025 | 43 | – |
| 10 | TFBF, sec | 0.050 ± 0.001 | 93 | – | 0.050 ± 0.001 | 93 | – |
| 11 | TSBF, sec | 0.051 ± 0.007 | 94 | – | 0.053 ± 0.008 | 98 | – |
| 12 | TMSF, sec | 0.101 ± 0.007 | 94 | – | 0.104 ± 0.009 | 96 | – |
| 13 | AFBF, Om | 0.0041 ± 0.0004 | 66 | – | 0.0042 ± 0.0005 | 68 | – |
| 14 | RI, Om | 0.0054 ± 0.0025 | 33 | 0.05 | 0.0066 ± 0.0031 | 40 | 0.05 |
| 15 | RVP, promille | 0.0295 ± 0.0110 | 47 | – | 0.0348 ± 0.0150 | 56 | – |
| 16 | Vq100, ml/min in 100 cm3 of tissue | 5.436 ± 0.595 | 140 | 0.05 | 7.536 ± 1.022 | 130 | – |
| 17 | IVO, % | 32.8 ± 17.2 | 239 | 0.05 | 17.2 ± 5.9 | 126 | – |
| 18 | DVI, % | 66.2 ± 7.9 | 141 | – | 52.4 ± 9.3 | 111 | – |
| 19 | ASPVC, mOm | 0.0054 ± 0.0026 | 35 | 0.05 | 0.0085 ± 0.0035 | 54 | – |

## DICUSSION

In all the patients, the basic impedance of the intramedullary tissues was lower than the basic impedance of paraosseous tissues. Thus, the way of wire-electrodes insertion provided a relative reduction in the impedance of intramedullary tissues and recording of its changes.

In children of both groups, the TPWD corresponded to average statistical values for femur that indicated the absence of impediments for blood inflow along the major and regional arteries. Thereby, it was lower in children of group 2 than in group 1. As far as the reduction in the TPWD happens by an increase in the density of the arterial walls [2], the tone of regional arteries walls was higher in children of group 2 in the limits of normal range changes than in children of group 1.

In all the children, the tone of walls of the regional (intraosseous) arteries was higher (increase in IVT and IEM) while the pulsed blood filling of the intramedullary tissues was lower (decrease in RI and RVP) than the average values for the femur. Thereby, the increase in the index of peripheral vessel resistance (IPVR) indicated the elevated tone (spasm) of resistive vessels that limited the blood flow along capillaries or at the thrombosis of the capillary flow portion. As far as there were no impediments for blood inflow along the major and regional arteries in the children of the analyzed group, one can suppose that the blood flow in the capillaries of the intraosseous tissues was reduced due to the elevation of the peripheral vessel resistance; and in order to increase it at the expense of axial pulsed oscillations of blood pressure the tone of walls of the regional vessels grew. Limitation of the capillary flow was more expressed in children of group 2 as far as the tone of the walls of the regional arteries increased. The changes were recorded at rest that indicated at the chronic blood circulation insufficiency.

The characteristics of pulse blood filling is mainly substantiated by the changes in the RI which accepted norm is 0.05–1.2 Om. Five grades of arterial blood supply are distinguished. The first grade has RVG wave amplitude from 0.05 to 0.04 Om, the second one from 0.04 to 0.03 Om, and the third one from 0.03 to 0.02 Om. These three grades reflect a compensated blood supply. The values from 0.02 to 0.01 Om are referred to a decompensated blood supply, and the ones that are less than 0.001 are critical [4]. The findings show that the pulse blood filling of the intramedullary tissues in the proximal growth zone of the femoral neck was compensated in children of group 1 and corresponded to the third grade of peripheral blood supply insufficiency while it was decompensated in children of group2.

The study revealed the presence of reactive and opposite directional changes in the functioning vessels in regard to tunnel perforation and cell-and-tissue transplantation.

The consequence of femoral neck tunnel perforation in the patients of group 1 was the increase in IPVR and IVO that indicated the spasm of resistive vessels and limitation of the venous blood outflow. The decrease in the RI and RVP proved the reduction of the pulse blood filling down to the level of decompensation. These changes were accompanied by the increase in the MVFBF (depends on the blood inflow along the major arteries) and volumetric flow velocity that in the conditions of the reduced pulse blood filling could be only a consequence of occurrence or increase of blood flow shunting. It could be supposed that the response to tunnel perforation was regional in group 1 and was expressed in the spasm of resistive vessels that caused limitation of the pulse blood filling and venous outflow from the microcirculation vessels that promoted the increase in blood flow shunting.

In children of group 2, the consequence of the femoral neck tunnel perforation was the decrease in BI (basic impedance) the value of which in rheovasography is in reverse proportion to blood filling [4]. Thereby, the amplitude of the systolic phase of the venous component (ASFVC) decreased. The increase in IPVR was lower but the IVO was more marked than in patients of group 1. The peculiarities of the rheographic indices indicate the insufficiency of the blood outflow along the veins and appearance of venous hyperemia. RI, MVFBF and AVSBF that were statistically significantly decreased proved a marked reduction in pulse blood filling down to the values that are characteristic of a critical ischemia. One of the causes of venous hyperemia was also the increase in the blood flow along the shunting vessels that was confirmed by the increase in the volumetric blood flow velocity (Vq100). The response to tunnel perforation in patients of group 2 was similar to the response in group 1 but the increased spasm of resistive vessels added to the increase of the venous outflow resistance that resulted in venous hyperemia and reduction in pulse blood filling to the values that are characteristic of a critical ischemia. It should be noted that this category of patients have a more marked predisposition to angiospasm.

The injection of the punctured cell-and-tissue resulted in a recovery (normalization) of the tone of the resistive vessels and volumetric blood flow velocity in group 1. The effect of the recovery (normalization) of the parameters provided the reduction in the tone of the walls of the middle caliber arteries (IEM). The inflow from the major arteries increased that was confirmed by the growth of the blood filling velocity of the pulse wave (MVFBF and AVSBF). It seems that the reduction in the amplitude parameters of the pulse wave that was recorded simultaneously and the limitation of the blood flow along the shunting vessels were the consequences of compression of the microcirculation vessels in the intramedullary tissues by an autologous blood injected into the bone.

The tone of the walls of the resistive vessels recovered in group 2. The effect was provided by the decrease in the tone of the walls of the middle caliber arteries. However, the decrease in BI and ASFVC was maintained by the increase of IVO that indicated the insufficiency of blood outflow along the veins and the presence of venous hyperemia. The decrease in the indices such as RI, MVFBF and AVSBF allows for a supposition that the blood outflow insufficiency was the reason of limitation of the velocity and blood filling of pulse wave while a retained increase in Vq100 points at the continuation of blood flow shunting. It seems that the disorder in venous outflow was one of the reasons that hindered the improvement of blood circulation.

As for the results of cell-and-tissue transplantation, a more marked response to it was noted in children of group 1 that was expressed as blood flow recovery along the microcirculation vessels and reduction in blood flow shunting. The decrease in the tone of the walls of the regional arteries of a middle caliber provided the effect. It resulted in the increase of blood inflow from large arteries. A distinguished feature of group 2 patients was limitation of the venous blood outflow that was a reason for retention of the reduction in pulse blood filling and blood flow shunting.

## CONCLUSION

Changes in the parameters of pulsed blood filling that indicate a compensated type of ischemia were revealed in children with avascular necrosis while they were of decompensation character in children with Perthes disease.

Tunnel perforation resulted in the regional spasm of the resistive vessels. It caused an additional limitation of pulsed blood filling in the intramedullary tissues and venous blood outflow limitation from the microcirculation vessels. Moreover, it resulted in the changes in the values of the parameters down to the ones that are characteristic of blood circulation decompensation in children with traumatic genesis of the pathology while in children with Perthes disease down to the level that is characteristic of critical ischemia. In children of group 2, an additional reason of blood circulation limitation was a hindered venous outflow as distinct from children of group 1. The changes that developed were temporal as it is known that tunnel perforation drains the injured area and activates angiogenesis that result in regional blood circulation improvement [6]. The injection of autologous blood with the elements of bone marrow resulted in the increase or recovery of the blood flow parameters, and eliminated the negative changes that appeared as a response to tunnel perforation. It confirms the feasibility of a combined use of tunnel perforation and cell-and-tissue transplantation in a complex treatment of this category of patients. A less marked response to injection of autologous blood with bone marrow elements in group 2 children points at a prevailing significance of venous outflow limitation in the increase of the ischemia severity. In order to enhance the draining effect, it is necessary to use a prolonged wire tunneling (during three to 4 weeks) as well as to repeat its performance in combination with cell-and-tissue transplantation after 2.5 or 3 months during the procedure of fixator removal.

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