Genij Ortopedii. 2022. Vol. 28, no. 4. P. 475-480.

Original article

https://doi.org/10.18019/1028-4427-2022-28-4-475-480

Immediate changes in pulsed blood filling in the articular ends of the ilium and femur after their perforation in Perthes disease

Vyacheslav S. Bunov✉**, Mikhail P. Teplenky, Evgenii V. Oleinikov**

Ilizarov National Medical Research Centre for Traumatology and Orthopedics, Kurgan, Russian Federation

Corresponding author: Vyacheslav S. Bunov, bvsbunov@yandex.ru

Abstract

Introduction In Perthes disease of stage 1 to 2, intraosseous pressure (IOP) of the tissue fluid in the head of the femur due to disorders of the venous outflow increases, the microvasculature is compressed and pulse blood supply is limited. To eliminate secondary circulatory insufficiency, the proximal femur and the supra-acetabular region of the ilium were perforated with wires, and differences in the pulse wave of blood filling in the femoral head associated with the order of perforation of the articular ends of the bones were revealed. **Purpose** To determine the dependence of the pulse wave of blood filling in the femoral head on the sequence of drilling of the supra-acetabular region of the ilium and the proximal femur in patients with Perthes disease. **Material and methods** A pulse wave of blood filling in the intraosseous tissues was recorded in 47 patients, aged 6-9 years, using rheovasography. In 6 patients, the supra-acetabular region of the ilium was perforated, then the proximal femur; in 41 patients the sequence was vice versa. **Results** In the hip joint, perforation of the articular end of one bone leads to post-traumatic angiospasm in the articular ends of both bones, and pulse blood supply decreases. However, by the initial perforation of the proximal end of the femur, the pulse blood supply to the tissues of the femoral head increases, and subsequent drilling of the supra-acetabular region of the ilium contributes to its additional increase. Taking into account the initially increased IOP in the femoral head, it was concluded that perforation leads to decompression of its microcirculatory bed, and pulse blood filling increases, and post-traumatic angiospasm does not develop. **Conclusion** In Perthes disease, the femoral head should be drilled first to decompress its microvasculature, then the supra-acetabular region of the ilium to redistribute blood circulation and further increase blood flow to the femoral head.

Keywords: Perthes disease, intraosseous tissues, tunneling, rheovasography

For citation: Bunov V.S., Teplenky M.P., Oleinikov E.V. Immediate changes in pulsed blood filling in the articular ends of the ilium and femur after their perforation in Perthes disease. *Genij Ortopedii*, 2022, vol. 28, no 4, pp. 475-480. DOI: 10.18019/1028-4427-2022-28-4-475-480.

INTRODUCTION

Due to disturbance in the outflow of blood through the central circumflex vein in the head of the femur, venous pressure and, accordingly, intraosseous tissue fluid pressure (IOP) increase, the microvasculature of the bone cavities is compressed by tissue fluid and limits blood flow in Perthes disease in stages 1 and 2 [1–13]. To prevent slowing down tissue regeneration due to secondary circulatory insufficiency, recommendations appeared to drill perforations in the proximal femur to decompress its vessels and to transplant bone marrow or angiogenic and osteogenic precursor cells with tissue repair activation factors into the femoral head [14–21]. In the Federal State Budgetary Institution Ilizarov NMRC for TO, an external fixator is used to unload the hip joint in patients with Perthes disease. Prior to applying the fixator and when the femoral head is fragmented, the proximal part of the bone and the supraacetabular region of the ilium are drilled with wires and an aspirate from the iliac wing is injected in the perforated wire tunnels into the femoral head as a medium for factors activating tissue repair [22–27]. Initially, the ends of the bones forming the hip joint were perforated in an arbitrary manner, however, we noticed the dependence of the pulse wave of blood filling in the femoral head on the order of perforation drilling. Therefore, this study was conducted.

Purpose To determine the dependence of the pulse wave of blood filling in the femoral head on the sequence of perforation drilling of the supra-acetabular region of the ilium and the proximal femur in patients with Perthes disease.

MATERIALS AND METHODS

The study was conducted in compliance with the ethical standards. Written consents of the parents for surgical intervention and publication of the results without personal identification were obtained. A total of 47 patients aged 6–9 years participated in the study, of which 13 (29%) were girls.

Criteria for inclusion in the study were Perthes disease in stage 2 (fragmentation) according to Waldenstrom, group III–IV according to Catterall, groups B/C and C according to Herring.

Exclusion criteria: aseptic necrosis of the femoral head of another etiology, Perthes disease in stages 1, 3, 4, Perthes disease stage II of I-II groups according to Catterall, groups A and B according to Herring.

The pulse wave of blood filling was recorded using the Rheograph-polyanalyzer RGPA-6/12 REAN-POLY (MEDICOM-MTD, Taganrog) at a probing electric current strength of 1.5 mA and a frequency of 56 Hz simultaneously in the intraosseous and paraosseous tissues, first in the femoral head, then lateral to the proximal growth plate of the femur and then in the supra-acetabular region of the ilium. Under the conditions of the operating room, before the planned surgical intervention, 1.8-mm wires for transosseous osteosynthesis were drilled into the studied bone areas, which served as electrodes and the position of which was not changed after installation (Fig. 1).

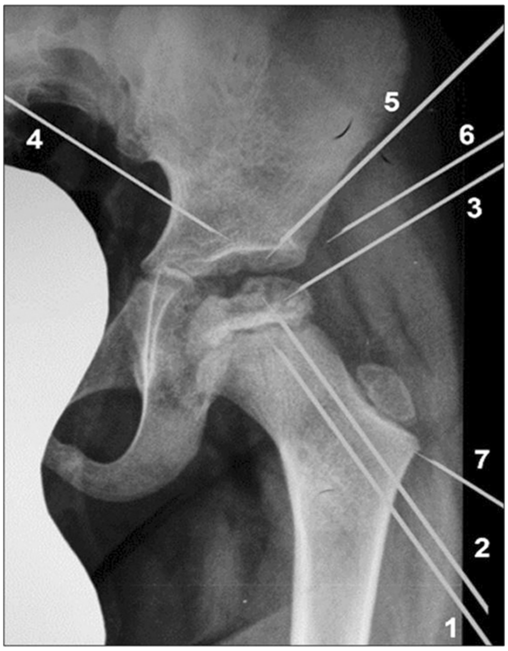

Fig. 1 Diagram of introducing electrodes for performing rheovasography in intraosseous and paraosseous tissues

Wires 1–3 were used to detect a pulse wave of blood filling in the intraosseous tissues lateral to the proximal growth zone of the femur; wires 2–3 ran in the intraosseous tissues of the femoral head; wires 4–5 in the intraosseous tissues of the supra-acetabular region of the ilium; wires 3–7 in the paraosseous tissues over the proximal femur; wires 4–6 in the paraossal tissues over the supra-acetabular region of the ilium. The relative decrease in the impedance (resistance to the probing alternating current) of the intraosseous tissues necessary for closing the electric current was determined on the monitor. Changes in the rheographic index (RI) were judged on the basis of the significance of differences in the means using Excel and the Wilcoxon T-test for related samples.

Drilling was performed with a 1.8 mm wire, which was immediately removed. The wire was inserted into the head of the femur according to the direction and depth of wire 2, four perforations were created; four perforations were made in the supra-acetabular region of the ilium, corresponding to the direction and depth of inserted wire 5. An aspirate from the iliac wing was taken using a Kassirsky needle and a syringe: blood was extracted with the contents of the bone marrow cavity in an amount of 1 ml. The femoral head was injected through a wire perforation tract using a long needle and syringe.

In group 1 (6 patients), the supra-acetabular region of the ilium was first perforated, then the head and neck of the femur, after which the aspirate was introduced into the head of the femur. In 41 patients of group 2, the femoral head was first perforated, then the supra-acetabular region of the ilium, and after that the aspirate was introduced into the femoral head in 27 patients.

RESULTS

RI in the femoral head had a minimum value in the patients of group 1 before drilling. After perforation in the supra-acetabular region of the ilium, RI decreased in all studied intraosseous tissues. In the head of the femur, its decrease was the least pronounced (Table 1).

Subsequent perforation of the proximal femur led to an increase in RI in all tissues studied. In the supra-acetabular region of the ilium and lateral to the proximal femoral growth zone, the increase was compensatory; in the femoral head, the index exceeded the value before tunneling, but the excess was not statistically significant (Table 2).

After the introduction of the aspirate into the femoral head, RI increased compensatory in the supra-acetabular region of the ilium and lateral to the proximal femoral growth zone and decreased in the femoral head, as a result of which the distribution of its values began to correspond to that before the onset of perforation: in the femoral head, its value became minimal (Table 3).

In the patients of the second group before drilling, RI in the femoral head had a minimum value. After perforation in the femoral head and neck, RI increased significantly only in the femoral head (Table 4).

Subsequent drilling of the supra-acetabular region of the ilium led to a decrease in RI in the intraosseous tissues of this region, an increase lateral to the proximal growth zone, and an additional increase in the femoral head (Table 5).

Upon introduction of the aspirate into the femoral head, the distribution of RI began to correspond to that before the onset of drilling in the patients of group 2: in the femoral head, its value became lower than in the intraosseous tissues of the supra-acetabular region of the ilium and lateral to the proximal femoral growth zone (Table 6).

Table 1

Changes in RI after drilling in the supra-acetabular region of the ilium in patients of group 1 (n = 6)

	Before	After	%	p <
Illium	0.0188 ± 0.0025	0.0070 ± 0.0010	37	0.05
Femoral head	0.0167 ± 0.0033	0.0124 ± 0.0021	74	–
Growth zone of the femur	0.0359 ± 0.0048	0.0173 ± 0.0042	48	0.05

Table 2

Changes in RI after drilling of the supra-acetabular region of the ilium and then of the femoral head in patients of group 1 (n = 6)

	Before	After	%	p <
Illium	0.0188 ± 0.0025	0.0100 ± 0.0019	53	0.05
Femoral head	0.0167 ± 0.0033	0.0212 ± 0.0051	127	–
Growth zone of the femur	0.0359 ± 0.0048	0.0322 ± 0.0058	90	–

Table 3

Changes in RI after drilling of the articular ends of the bones and the introduction of aspirate into the femoral head in patients of group 1 (n = 6)

	Before	After	%	p <
llium	0.0188 ± 0.0025	0.0178 ± 0.0021	95	–
Femoral head	0.0167 ± 0.0033	0.0163± 0.0025	98	–
Growth zone of the femur	0.0359 ± 0.0048	0.0361 ± 0.0065	101	–

Table 4

Changes in RI in group 2 patients after drilling of the femoral head and neck (n = 41)

	Before	After	%	p <
Illium	0.0240 ± 0.0020	0.0257 ± 0.0025	107	–
Femoral head	0.0227 ± 0.0021	0.0377± 0.0044	166	0.01
Growth zone of the femur	0.0256 ± 0.0018	0.0264 ± 0.0026	103	–

Table 5

Changes in RI in patients of group 2 after drilling of the head and neck of the femur, and then of the supra-acetabular region of the ilium (n= 41)

	Before	After	%	p <
Illium	0.0240 ± 0.0020	0.0179 ± 0.0019	75	0.05
Femoral head	0.0227 ± 0.0021	0.0391± 0.0042	172	0.01
Growth zone of the femur	0.0256 ± 0.0018	0.0386 ± 0.0047	151	0.05

Table 6

Changes in RI in patients of group 2 after drilling and introduction of aspirate (Ta) into the femoral head (n = 27)

	After drilling	Aspirate injection	%	p <
Illium	0.0308 ± 0.0030	0.0290 ± 0.0032	94	–
Femoral head	0.0310 ± 0.0036	0.0228 ± 0.0028	74	–
Growth zone of the femur	0.0263 ±0.0022	0.0257 ± 0.0027	98	–

DISCUSSSION

Circulating blood is an electrolyte that provides the lowest resistance to electric current. Therefore, during rheovasography, the closure of the probing electric current of the rheograph occurs mainly in the blood, and changes in impedance (complex resistance of tissues to the probing current) are proportional to changes in the blood filling of the pulse wave. The rheographic index (RI) is the ratio of the amplitude of the blood filling pulse wave to the height of the standard calibration signal; it is recognized as the equivalent of the pulse blood filling of the vessels in the interelectrode space [28, 29].

The bone substance has a high electrical resistance [30]. By separating the intraosseous and paraosseous tissues, it creates the possibility of a separate circuit of the probing electric current in these tissues. In order for the closure to take place in the intraosseous tissues, their impedance was reduced: the distance between the ends of the wires inserted into the bone was reduced relative to the distance between the sections of the same wires in the paraosseous (extraosseous) tissues. The initial decrease in the impedance of the intraosseous tissues, which persisted during the study, enabled to use wire electrodes without an insulating coating [31, 32].

Initially, the pulse blood supply to the tissues of the femoral head was less than that of the supra-acetabular region of the ilium and lateral of the proximal femoral growth zone in the patients of both groups.

In patients of group 1, perforation of the supra-acetabular region of the ilium led to a decrease in pulse blood flow to the studied tissues. A typical reaction to trauma is known to be post-traumatic angiospasm (a transient increase in the tone of vessel walls) [30]. Consequently, angiospasm spread to the tissues of the proximal femur from the supra-acetabular region of the ilium, and was the cause of a decrease in pulse blood supply to the intraosseous tissues in the articular ends of the bones.

Subsequent perforation of the femoral head led to an increase in pulse blood filling to its tissues and a compensatory increase in pulse blood filling in the intraosseous tissues of the supra-acetabular region and lateral of the proximal femoral growth zone. The drilled tunnels ensured the outflow of tissue fluid from the femoral head. Due to a decrease in the pressure of the tissue fluid from the outside, the microvasculature might have expanded under blood pressure, and the filtration of the fluid into the extravascular space increased. Corresponding to the increase in the capacity and volume of filtration, the blood pressure in the microcirculatory bed decreased. To fill it, the blood flow from the arteries increased, and their pulse blood filling increased. Decompression vasodilatation of the microvasculature prevented the development of post-traumatic angiospasm in the femoral head, and an increase in pulse blood supply to the arteries of the femoral head reduced its severity in the supra-acetabular region of the ilium and lateral to the proximal femoral growth zone.

The introduction of aspirate increased the IOP in the femoral head, and pulse blood filling changed opposite to that after drilling. In the intraosseous tissues of the femoral head, RI became lower than in the intraosseous tissues of the supra-acetabular region of the ilium and lateral to the proximal femoral growth zone. The restored ratio of the RI value confirmed the dependence of the pulse blood filling of the tissues on the IOP.

In patients of group 2, the femoral head was initially drilled, and, just like in patients of the first group, an increase in pulse blood filling of its tissues was obtained due to decompression of the vessels of the microvasculature.

Subsequent drilling of the supra-acetabular region of the ilium led to a decrease in pulse blood supply to the iliac tissues, an increase lateral from the proximal femoral growth zone, and an additional increase in the femoral head. It means that with IOP in the range of the physiological norm (iliac bone), the drilling led to the development of post-traumatic angiospasm, and with an increased IOP (femoral head), the development of angiospasm stopped due to decompression dilatation of the microvasculature. Moreover, probably due to a decrease in the capacity of the vascular bed of the intraosseous tissues of the ilium, the portions of blood intended for these tissues moved through vascular relations to the intraosseous tissues of the proximal femur – to the microvasculature in a state of dilatation.

The introduction of aspirate increased the IOP in the femoral head, and the distribution of RI in the studied intraosseous tissues turned to correspond to that before tunneling: in the intraosseous tissues of the femoral head, its value became lower than in the intraosseous tissues of the supra-acetabular region of the ilium and lateral from the proximal femoral growth zone.

Thus, the drilling of the articular end of the bone with wires led to the appearance of post-traumatic angiospasm, which spread to the intraosseous tissues of the articular end of another bone: in the hip joint, the vascular bed of the intraosseous tissues of the articular ends of the bones reacted to injury in an interconnected manner.

Post-traumatic angiospasm, as a reaction to drilling with wires, developed at an adequate IOP for the articular end of the bone and caused a decrease in pulse blood filling. In case of increased intraosseous blood pressure, decompression of the microvasculature contributed to an increase in pulse blood filling of the intraosseous tissues and thus prevented the development of post-traumatic angiospasm.

Drilling of the supra-acetabular region of the ilium after perforation of the femoral head led to a redistribution of blood circulation, as a result of which the pulsed blood filling to the femoral head additionally increased.

The introduction of aspirate impulsively increased the IOP in the femoral head, and the distribution of the RI value in the studied tissues changed to match that with the initially elevated IOP: it became minimal in the femoral head, which confirmed the dependence of the response of the vessels of the intraosseous tissues to drilling on the initial IOP value.

CONCLUSIONS

To improve blood circulation in the femoral head in Perthes disease, one should follow the sequence of drilling of the articular ends of the bones. The femoral head should be perforated first in order to reduce IOP, which provides decompression vasodilation of its microcirculatory bed. Next, the supra-acetabular region of the ilium should be drilled to further increase blood flow to the head and proximal zone growth of the femur due to the redistribution of blood circulation. Finally, if necessary, to introduce factors for activating tissue repair into the head of the femur.

REFERENCES

1. Iwasaki K., Suzuki R., Okazaki T., Ikeda S., Inoue Y., Shimauchi R. The haemodinamics of Perthes' disease. An intraosseous venographic study combined with measurement of the intramedullary pressure. *Int. Orthop*., 1982, vol. 6, no. 3, pp. 141-148. DOI: 10.1007/BF00267723.
2. Liu S.L., Ho T.C. The role of venous hypertension in the pathogenesis of Legg-Perthes disease. A clinical and experimental study. *J. Bone Joint Surg. Am*., 1991, vol. 73, no. 2, pp. 194-200.
3. Herrin J.A., Tachdjian M.O. *Tachdjian's pediatric orthopaedics*. 4th edition. Vol. 1. Philadelphia, Saunders/Elsevier, 2008, pp. 771-837.
4. Hungerford D.S., Lennox D.W. The importance of increased intraosseous pressure in the development of osteonecrosis of the femoral head: implications for treatment. *Orthop. Clin. North. Am*., 1985. Vol. 16, No 4. P. 635-654.
5. Chesnokova N.P., Morrison V.V., Afanaseva G.A., Polutova N.V. Mestnye oteki. Etiologiia, patogenez protsessov ekssudatsii i transsudatsii [Local edema. Etiology, Pathogenesis of the processes of exudation and transudation]. *Nauchnoe obozrenie. Meditsinskie nauki* [Scientific review. Medical Sciences]. 2016, no. 1, pp. 69-73. (in Russian)
6. Mustafin R.N., Khasnutdinova E.K. Avaskuliarnyi nekroz golovki bedrennoi kosti [Avascular necrosis of the femoral head]. *Tikhookeanskii Meditsinskii Zhurnal* [Pacific Medical Journal], 2017, no. 1, pp. 27-35. (in Russian)
7. Torgashin A.N., Rodionova S.S., Shumskii A.A., Makarov M.A., Torgashina A.V., Akhtiamov I.F., Kovalenko A.N., Zagorodnii N.V., Mironov S.P. Lechenie asepticheskogo nekroza golovki bedrennoi kosti. Klinicheskie rekomendatsii [Treatment of aseptic necrosis of the femoral head. Clinical guidelines]. *Nauchno-prakticheskaia Revmatologiia* [Scientific and Practical Rheumatology], 2020, vol. 58, no. 6, pp. 637-645. (in Russian)
8. Beaulé P.E., Jarvis J.G., Castle W.G., Bormanis J. Protein-c deficiency in a patient with Legg-Calvé-Perthes disease and recurrent deep vein thrombosis. *Orthopedics*, 2002, vol. 25, no. 5, pp. 541-543. DOI: 10.3928/0147-7447-20020501-10.
9. Green N.E., Griffin P.P. Intra-osseous venous pressure in Legg-Perthes disease. J. Bone Joint Surg. Am., 1982, vol. 64, no. 5, pp. 666-671.
10. Shah H. Perthes disease: evaluation and management. *Orthop. Clin. North Am*., 2014, vol. 45, no. 1, pp. 87-97. DOI: 10.1016/j.ocl.2013.08.005.
11. Kim H.K. Pathophysiology and new strategies for the treatment of Legg-Calvé-Perthes disease. *J. Bone Joint Surg. Am*., 2012, vol. 94, no. 7, pp. 659-669. DOI: 10.2106/JBJS.J.01834.
12. Pavone V., Chisari E., Vescio A., Lizzio C., Sessa G., Testa G. Aetiology of Legg-Calvé-Perthes disease: A systematic review. *World J. Orthop*., 2019, vol. 10, no. 3, pp. 145-165. DOI: 10.5312/wjo.v10.i3.145.
13. Guerado E., Caso E. The physiopathology of avascular necrosis of the femoral head: an update. *Injury*, 2016, vol. 47, no. Suppl. 6, pp. S16-S26. DOI: 10.1016/S0020-1383(16)30835-X.
14. Chotivichit A., Korwutthikulrangsri E., Pornrattanamaneewong C., Achawakulthep C. Core decompression with bone marrow injection for the treatment of femoral head osteonecrosis. *J. Med. Assoc. Thai*., 2014, vol. 97, no. Suppl. 9, pp. S139-S143.
15. Wang W., Liu L., Dang X., Ma S., Zhang M., Wang K. The effect of core decompression on local expression of BMP-2, PPAR-γ and bone regeneration in the steroid-induced femoral head osteonecrosis. *BMC Musculoskelet. Disord*., 2012, vol. 13, pp. 142. DOI: 10.1186/1471-2474-13-142.
16. Li R., Lin Q.X., Liang X.Z., Liu G.B., Tang H., Wang Y., Lu S.B., Peng J. Stem cell therapy for treating osteonecrosis of the femoral head: From clinical applications to related basic research. *Stem Cell Res. Ther*., 2018, vol. 9, no. 1, pp. 291. DOI: 10.1186/s13287-018-1018-7.
17. Tikhilov R.M., Shubniakov I.I., Miasoedov A.A., Irzhanskii A.A. Sravnitelnaia kharakteristika rezultatov lecheniia rannikh stadii osteonekroza golovki bedrennoi kosti razlichnymi metodami dekompressii [Comparative characteristics of the results of treatment of early stages of osteonecrosis of the femoral head by various methods of decompression]. *Travmatologiia i Ortopediia Rossii* [Traumatology and Orthopedics in Russia], 2016, vol. 22, no. 3, pp. 7-21. (in Russian)
18. Herrera-Soto J.A., Price C.T. Core decompression for juvenile osteonecrosis. *Orthop. Clin. North Am*., 2011, vol. 42, no. 3, pp. 429-436, ix. DOI: 10.1016/j.ocl.2011.04.004.
19. Aruwajoye O.O., Monte F., Kim A., Kim H.K.W. A Comparison of Transphyseal Neck-Head Tunneling and Multiple Epiphyseal Drilling on Femoral Head Healing Following Ischemic Osteonecrosis: An Experimental Investigation in Immature Pigs. *J. Pediatr. Orthop*., 2020, vol. 40, no. 4, pp. 168-175. DOI: 10.1097/BPO.0000000000001219.
20. Wang Z.L., He R.Z., Tu B., He J.S., Cao X., Xia H.S., Ba H.L., Wu S., Peng C., Xiong K. Drilling Combined with Adipose-derived Stem Cells and Bone Morphogenetic Protein-2 to Treat Femoral Head Epiphyseal Necrosis in Juvenile Rabbits. Current Medical Science, 2018, vol. 38, pp. 277-288.
21. Craveiro Lopes N. [Legg-Calvé-Perthes disease. Current Concept Review]. *Rev. Port. Ortop. Traum*., 1994, vol. 2, no. 1, pp. 75-79. (in Portuguese)
22. Ibrahim Y.H., Kersh M.A.A.L., Fahmy H. Arthrodiastasis in the management of Perthes disease: a systematic review. *J. Pediatr. Orthop. B*, 2020, vol. 29, no. 6, pp. 550-555. DOI: 10.1097/BPB.0000000000000690.
23. Sudesh P., Bali K., Mootha A.K., Dhillon M.S., Saini R. Arthrodiastasis and surgical containment in severe late-onset Perthes disease: an analysis of 14 patients. *Acta Orthop. Belg*., 2010, vol. 76, no. 3, pp. 329-334.
24. Makushin V.D., Teplen'kii M.P., Parfenov E.M. A new treatment technique for the hip osteochondropathy using epiphyseal implantation of bone marrow suspension. *Genij Ortopedii*, 2013, no. 2, pp. 109-111. (in Russian)
25. Teplen'kii M.P., Parfenov E.M. Surgical treatment of children with severe forms of Perthes disease. Genij Ortopedii, 2013, no. 1, pp. 32-35. (in Russian)
26. Bunov V.S., Teplen'kii M.P., Oleinikov E.V. Characteristic features of hemodynamics in the femoral neck of children with femoral head aseptic necrosis. *Genij Ortopedii*, 2016, no. 4, pp. 50-55. DOI 10.18019/1028-4427-2016-4-50-55.
27. Bunov V.S., Oleinikov E.V., Parfenov E.M. Changes in hemodynamics of the hip components of the patient with Perthes disease during treatment using the Ilizarov fixator(for practitioners and researchers). *Genij Ortopedii*, 2013, no. 1, pp. 128-131. (in Russian)
28. Zenkov L.R, Ronkin M.A. *Funktsionalnaia diagnostika nervnykh boleznei: rukovodstvo dlia vrachei. 5-e izd*. [Functional diagnosis of nervous diseases: a guide for physicians. 5th Ed.]. M., MEDpress-inform; 2013, pp. 313-380. (in Russian)
29. *Reograf-polianalizator shestikanalnyi dlia kompleksnogo issledovaniia parametrov krovoobrashcheniia RGPA-6/12 "REAN-POLI": rukovodstvo polzovatelia* [Six-channel rheograph-polyanalyzer for a comprehensive study of blood circulation parameters RGPA-6/12 "REAN-POLY": user manual]; Taganrog; 2005, 173 p. (in Russian)

30. Vitsleb E. Funktsii sosudistoi sistemy [Functions of the vascular system]. In: Shmidt R., Tevs G., editors. *Fiziologiia cheloveka* [Human Physiology]. In 3 Vol. Transl. from English. M., Mir; 1996, vol. 2, pp. 498-566. (in Russian)
31. Teplenky M.P., Makushin V.D. *Lechenie displazii tazobedrennogo sustava u detei: monografiia* [Treatment of the hip dysplasia in children: monograph (Russian Edition)]. LAP LAMBERT Academic Publishing; 2017, 384 p. (in Russian)
32. Sviridenko A.S., Bunov V.S., Biriukova M.Iu., Liulin S.V., Meshcheriagina I.A. Osobennosti krovoobrashcheniia v myshchelkakh bedrennoi i bolshebertsovoi kostei pri gonartroze 2 stepeni [Features of blood circulation in the condyles of the femur and tibia in gonarthrosis of the 2nd degree]. *Mezhdunarodnyi Zhurnal prikladnykh i fundamentalnykh issledovanii* [International Journal of Applied and Basic Research], 2016, no. 3-1, pp. 94-99. (in Russian)

The article was submitted 01.11.2021; approved after reviewing 15.11.2021; accepted for publication 23.05.2022.

Information about the authors:

1. Viacheslav S. Bunov – Candidate of Medical Sciences, bvsbunov@yandex.ru;
2. Mikhail P. Teplenky – Doctor of Medical Sciences, teplenkiymp@mail.ru;
3. Evgenii V. Oleinikov – Candidate of Medical Sciences, orto-kgn@mail.ru.