Efficiency and Safety of Tourniquet during Total Knee Arthroplasty: When to Perform Release?

D.V. Chugaev, N.N. Kornilov, P.G. Kogan

Vreden Russian Research Institute of Traumatology and Orthopedics
8, ul. Akad. Baykova, St. Petersburg, 195427, Russia

Abstract

Use of a pneumatic tourniquet during total knee arthroplasty is an effective option allowing reduction of the time of surgery and intraoperative blood loss. At the same time, there are a lot of researchers who advocate differing tactical approaches to the duration of the tourniquet application — the so-called "early" and "late" releases.

Purpose of the study: to assess the effectiveness and safety of various methods of tourniquet use during primary total knee arthroplasty.

Material and Methods. 72 patients with end-stage knee osteoarthritis were randomly divided into two equal prospective groups: 1) keeping the tourniquet throughout the surgery, including wound closure (late release); 2) performing knee arthroplasty using the tourniquet until after implantation of the prosthesis component and implementation of hemostasis after the release of the tourniquet (early release). Such aspects as perioperative blood loss and changes in blood counts, blood transfusion volume, and severity of pain on the VAS scale, the rate of recovery of the knee joint function and number of postoperative complications were assessed during hospital stay of patients.

Results. The duration of procedures was 70±15,4 min for the Group I with tourniquet throughout surgery (late release) and 95±27,5 for the Group II with early release (p = 0,001). On the 7th day after the arthroplasty the authors observed statistically significant differences (p<0,05) in the dynamics of reducing the level of hemoglobin, red blood cells and hematocrit in patients of compared groups — in patients who underwent late release of the tourniquet, these indicators were higher. When assessing the rate of recovery of knee joint function according to the KSS -and the intensity of the pain syndrome no significant statistical differences were found in the patients of both groups.

Conclusion. Application of the tourniquet throughout the surgery to release after closure of the surgical wound does not lead to a sharp increase in the number of ischemic and thromboembolic complications, while at the same time, the application of this methodology to a large extent maintains hemoglobin indicators, red blood cells and hematocrit at a high level without a critical decrease.

Keywords: knee arthroplasty, intraoperative blood loss, tourniquet, drain.

DOI: 10.21823/2311-2905-2017-23-4-9-17

Introduction

Despite the opinion of certain authors that application of tourniquet during TKA can be associated with ischemic lesions of quadriceps muscle, more pronounced pain syndrome in postoperative period, problems with healing of the surgical wound and increased rate of thromboembolic complications the tourniquets are widely used in orthopaedic surgery [1–6]. Certain evident advantages of tourniquet contribute to such practice, like shortening of surgery time, decrease of intraoperative blood loss, perfect visualization during procedure and provision of optimal conditions for cemented fixation of prosthesis [7–9].

Currently there are several methods utilized in TKA:

1) use of tourniquet ensuring minimal blood loss during the procedure though not enabling adequate hemostasis;

2) refusal to use tourniquet during the surgery which does not prevent meticulous consistent hemostasis at various stages of procedure;

3) tourniquet application during surgery, tourniquet release, performance of hemostasis and closing of operative wound without tourniquet [10].

Cite as: Chugaev D.V., Kornilov N.N., Kogan P.G. [Efficiency and Safety of Tourniquet during Total Knee Arthroplasty: When to Perform Release?]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2017;23(4): 9-17. (in Russian). DOI: 10.21823/2311-2905-2017-23-4-9-17.

Dmitry V. Chugaev. 8, ul. Akad. Baykova, St. Petersburg, 195427, Russia; e-mail: dr.chugaev@gmail.com

Received: 31.08.2017. Accepted for publication: 01.11.2017.

Apart from the fact of using tourniquet during TKA, it's application method can significantly influence development of complications and its efficiency depending, in particular, on the procedure stage for tourniquet release [7]. On the one hand, the tourniquet application until cement polymerization, tourniquet's early release and hemostasis allow to evaluate the soft tissues bleeding rate, to coagulate vessels damaged during the procedure, but, on the other hand, due to postischemic hyperemia the bleeding can be more significant as compared to absence of tourniquet and leads to a bigger volume of intraoperative blood loss during short period of time [11].

Many authors studying various methods of tourniquet application recommend to use it during the whole surgical procedure with right closing of surgical wound without draining of the knee joint cavity [12,13]. Widespread utilization of such approach limits rational concerns of many orthopaedic surgeons regarding possible intraoperative damage of large vessels, absence of control over hemostasis and risk of development of postoperative hemarthrosis. Time of surgery exceeding 1,5-2 hours can become a factor determining need for tourniquet release in order to avoid ischemic lesion of soft tissues and increased risk of thromboembolic complications [14]. Though the majority of modern studies confirm efficiency of such tactics in regard of blood preservation and it's safety in regard to development of postoperative complications [15], the literature analysis reveals controversial conclusions of researches that often propagate the opposite approaches to blood preservation in primary TKA that do not allow to confidently select a single definitive approach.

Purpose of the study: то assess the effectiveness and safety of various methods of tourniquet use during primary total knee arthroplasty.

Material and methods

Patients with knee osteoarthritis combined with varus deformity at knee level (frontal deformity up to 25°) prevailed in the study. Patients with extensive defects of knee joint bones requiring various methods of grafting and use of prosthesis with enhanced frontal stabilization were excluded from the study.

72 patients with end-stage of knee osteoarthritis that required TKA with BMI below 42 were randomly divided into two prospective groups depending on type of surgical blood preserving methods:

I group (late tourniquet release) where the tourniquet was kept throughout the whole surgery, including wound closure;

II group (early tourniquet release) where tourniquet was applied until completion of implantation of the prosthesis components and implementation of hemostasis after the release of the tourniquet with following surgical wound closure.

Mean age of patients in the group with late tourniquet release was 64,6±7,5 years, in the group with early release (prior to wound closure) — 63,9±6,7 years. The authors observed no statistically significant differences in age criteria (p>0,05) (Fig. 1).

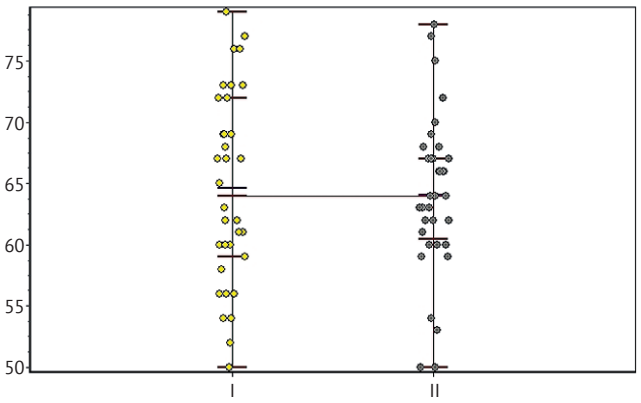

Fig. 1. Patients distribution depending on age (group I — tourniquet during the whole surgery without drain, group II — tourniquet release prior to wound closure and hemostasis without drain) (*p*>0,05)

Surgical treatment of patients

The authors used spinal anesthesia with bupivocaine of 15-20 mg. All patients were intravenously administered 1,5 g of tranexamic acid 30 minutes before the surgery. Patients were operated in supine position, operated lower limb was fixed by support of fracture table, tourniquet was applied on the upper third of femur and inflated until pressure of 270-300 mm Hg. The authors used anterior approach to the knee joint (anteromedial for patients with varus deformity and anterolateral Keblish approach for patients with valgus deformity). Using standard instrument set for knee arthroplasty and common methods the authors performed bone resections of femur and tibia, prepared bone beds for prosthesis components, made cementing and closing of the wound. In both groups the prostheses preserving anterior cruciate ligament (CR) prevailed — 87%. Drainage of the knee joint cavity was not performed in patients of the studied groups.

Both groups were compared in relation to the following criteria: volume of intra- and postoperative blood loss, laboratory blood data (hemoglobin, red cells count, hematocrit), need for hemotransfusion, VAS pain severity score, restoration of knee function (support ability, range of motion and weight bearing), rate of postoperative complications.

After obtaining benchmark data of the patients Microsoft Excel was used for compiling electronic tables. Generally available and free software InStat+ ver.3.37 (2005) and Past ver.2.17 (2012) were used for statistical data processing.

Results

Mean duration of procedures was 70±15,4 min for the group with tourniquet throughout the whole surgery (Group I – late release) and 95±27,5 for the group with early release with hemostasis prior to wound closure (Group II) (Fig. 2). Procedures in Group I with tourniquet kept throughout the whole surgery took reliably less time than in Group II (p = 0,001) where hemostasis was made prior to wound closure. Mean time of surgery was shorter in Group I at 15±11,6 min as compared to Group II.

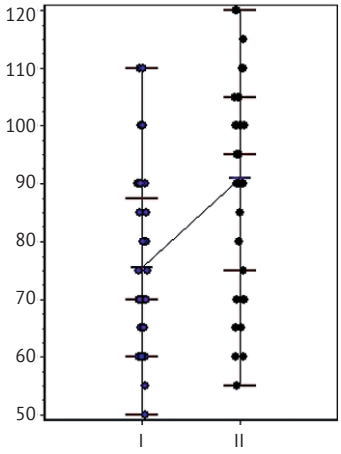

Fig. 2. Surgery time in studied groups, min (p = 0,001)

During evaluation of obtained data on intraoperative blood loss, the statistical evaluation of blood loss criteria in Group I as compared to Group II was not performed due to zero blood loss in Group I (Fig. 3).

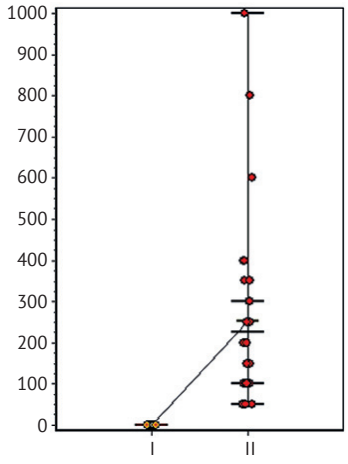

Fig. 3. Intraoperative blood loss in studied groups, ml

When evaluating hemoglobin level in studied patients prior to surgery the authors did not observe statistically different criteria (p = 0,9) (133,4±12,3 g/l in Group I (I on fig. 4) and 132±12,5 g/l in Group II (III on fig. 4)). On the 7th day after the arthroplasty the authors observed statistically significant differences (p = 0,02)in the dynamics of reducing the level of hemoglobin in compared groups, mean values were 108,4±14,5 g/l (Group I) (II on fig. 4) and 96,9±10,7 g/l (Group II) (IV on fig. 4). Difference in hemoglobin levels prior/after the surgery amounted to 24,9±12,5 g/l, and 35±12,3 g/l for Group II, where obtained values were statistically reliable (p = 0,03).

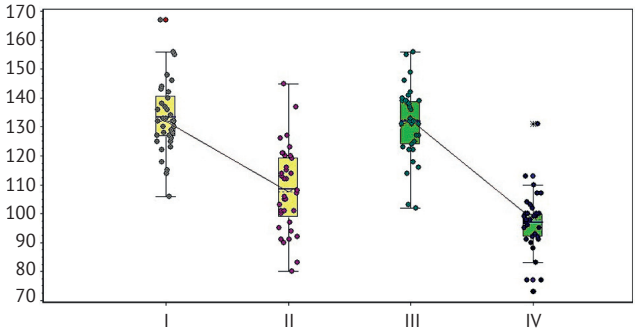

Fig. 4. Hemoglobin values prior to surgery and on 7th day after the surgery in studied groups, g/l

Red blood cells count in the blood of studied patients prior to surgery did not statistically different (p = 0,3) (I and III on fig. 5) but after the procedure demonstrated a similar to hemoglobin decrease dynamics, more pronounced in the group of patients where hemostasis was performed prior to wound closure (p = 0,04) (II and IV on fig. 5). Difference in red blood cells count level prior/after the procedure for the group with later release amounted to 0,9±0,4 g/l, and 1,06±0,4 g/l in the group with early release.

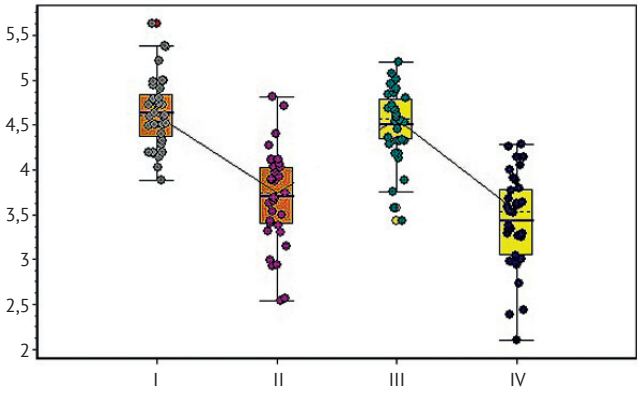

Fig. 5. Red blood cells level prior to surgery and on 7th day after the surgery in the groups, $\times 10^{12}$

Hematocrit levels in preoperative period (I and III on fig.6) also demonstrated no statistical difference (p = 0,7); in early postoperative period difference in hematocrit level for later release group amounted to 0,07±0,04 g/l, and 0,1±0,03 g/l for the early release group.

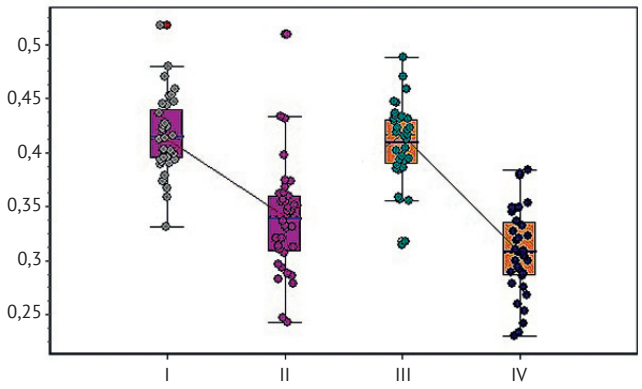

Fig. 6. Hematocrit levels prior to surgery and on 7th day after the surgery in the groups, g/l

Number of knee joint aspirations in postoperative period was comparable in both groups, however the volume of evacuated blood from the joint was higher in Group II where tourniquet release and hemostasis was performed prior to wound closure (p<0,05) (Fig. 7).

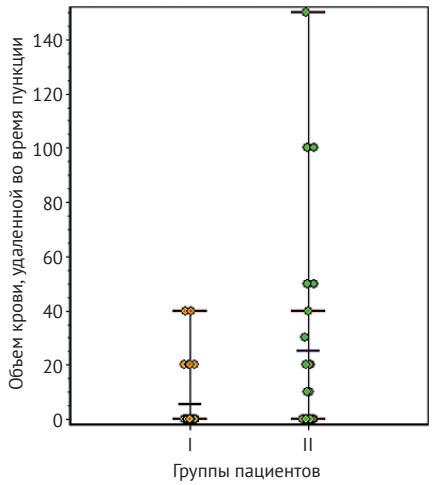

Fig. 7. Blood volume evacuated from joint space during aspiration, ml

Hemotransfusion was required in two cases of patients from Group II where tourniquet release and hemostasis were performed prior to wound closure. One postoperative complication per each group was reported: wound border necrosis in Group I which was successfully treated conservatively, and wound hematoma in Group II which required sanation of the wound with following favorable clinical outcome.

No statistically significant differences in patients of both groups were observed in regard of knee function recovery rate by KSS, pain syndrome intensity and weight bearing ability. No cases of periprosthetic infection were observed during 3 months of postoperative period in patients of both groups.

Discussion

High volume of perioperative blood loss during TKA is resulting from various factors like additional surgical trauma, abundant vascularization of soft tissues around knee joint, presence of extensive bone wounds (bone beds for implants) [16,17]. Diffuse bleeding of soft tissues and bone cuts results in worse visualization of operative wound, deteriorates cemented technique and leads to posthemorrhagic anemia in postoperative period that require simple and efficient prophylaxis for above negative arthroplasty factors.

No thromboembolic complications were reported in patients of both groups, however it's worth noting that in current conditions the rate of such complications is so minor that patient groups should be significantly larger to study tourniquet effect, refusal from drainage and other factors. The best values of hemoglobin, red blood cells and hematocrit were observed in the group with late tourniquet release. The experience of described technique allowed the authors to find that refusal to do hemostasis after the main stage of surgery does not result in the need to perform multiple aspirations of the knee joint. The issue of so called early tourniquet release and it's necessity is actively discussed in the literature however no consensus has been reached so far. Thus, Zhang et al. after analysis of 16 studies concluded that early tourniquet release (prior to wound closure) statistically reliable increases volume of perioperative blood loss which substantially offsets favorable tourniquet effects, however, at the same time hemostasis prior to wound closure allows to decrease the rate of perioperative complications, primarily of lesser infection complications [18]. The authors obtained similar outcomes in the present study where the group of patients with early tourniquet release demonstrated worse outcomes in respect of hemoglobin/red blood cells/hematocrit decrease and the volume of blood evacuated during aspirations as compared to the group of patients with late tourniquet release. Meta-analysis by Rama et al. also dem-

onstrated statistically reliable blood preserving effect of tourniquet release after wound closure, although as in meta-analysis of Zhang et al. the number of complications related to wound healing was higher [7]. Yildiz et al. observed similar data, analysis of which demonstrated that tourniquet release after wound closure and closure of drainage during first 6 hours after the surgery allowed to decrease postoperative blood loss and the value of hemoglobin level decrease [19]. Such tactics was confirmed by meta-analysis of Tai who demonstrated that drainage closure after TKA for 3-4 hours has no negative influence over the number of postoperative complications and rehabilitation, but substantially decreases drainage blood loss and favorably influences hemoglobin level in patients in the postoperative period [20].

The logical follow up of drainage closure is the application of tourniquet with its release after wound closure and refusal of knee joint drain. Padala et al. used medication cocktail with adrenalin intraoperatively and did not drain the knee cavity and concluded that the present method yields good blood preserving result and is safe for the patient [21]. The authors of the present study proceeded likewise and refused draining of knee joint and such decision did not result, as in other studies, in statistically different arthroplasty outcomes (disturbance of surgical wound healing, recurrent massive hemarthrosis, deep infection, problems with early rehabilitation).

Oh et al. performed an original research where to evaluate the safety of tourniquet application and to minimize the risk of complications primarily in elderly patients they studied the ischemic preconditioning effect which includes preparation of brain and other internal organs to sharp increase of metabolites concentration after tourniquet release. Researchers applied tourniquets on both femurs of patient and activated the cuff on the contralateral limb three times with 15 minutes exposure. Obtained data demonstrated that described method significantly decreases negative effect of tourniquet application and can be routinely used predominantly in elderly patients [22]. Each of the methods described above has positive and negative aspects, however currently is used only based on the surgeon preferences and it can be concluded that neither in Russia nor abroad there is a unity in determination of the most rational tactics for tourniquet application.

All above mentioned studies have certain limitations related to the number of patients, used implants (only posteriorly stabilized prostheses or prostheses of CR type), use or refusal to use drainage. Undoubtedly the present research also has limitations while the authors did not study results of tourniquet application in patients with knee osteoarthritis accompanying with severe destruction of the joint, in patients after revision arthroplasty. Due to longer surgery time and significant technical difficulties the time of procedure exceeds allowable tourniquet exposure, pathologically altered soft tissues of the knee joint in revision procedures are featured by more intensive bleeding as compared to soft tissues of intact knee. Patients with end-stage obesity are also not the most favorable objects for tourniquet application during TKA while strongly pronounced subcutaneous fat layer does not allow the tourniquet cuff to provide sufficient compression and effective use of the tourniquet. In the present study the authors did not consider as complication a marked imbibition of skin and subcutaneous fat by flood while the authors did not find a correlation between so called “hematomas” and significant decrease of hemoglobin level and red blood cells with complicated early rehabilitation.

Conclusion

Volume of blood loss in both groups was not critical considering that majority of patients underwent standard primary TKA not requiring bone defects replacement or use of revision systems. At the same time preoperatively existing anemia, hidden blood loss, capillary hemorrhage continuing after wound closure and other factors resulted in development of posthemorrhagic anemia in studies patients.

Application of the tourniquet throughout the surgery to release after closure of the surgical wound does not lead to a sharp increase in the number of ischemic and thromboembolic complications, while at the same time, the application of this methodology to a large extent maintains hemoglobin indicators, red blood cells and hematocrit at a high level without a critical decrease.

During analysis of dynamics in changes of hemoglobin, red blood cells and hematocrit values the best values were observed in the group with late tourniquet release without drainage and without hemostasis prior to wound closure. Experience in above method application allows to conclude that refusal to do hemostasis after the main surgical stage does not result to increased rate of knee aspirations. Dynamics of pain syndrome and functional recovery rate was on the comparable levels without statistically reliable differences. Thus, it can be concluded that late tourniquet release and absence of knee joint drainage without hemostasis is a safe and efficient procedure with high blood preserving capacity. Use of tourniquet within 270-300 mm Hg does not lead to increase of pain syndrome and is not associated with higher postoperative complication rate and can be recommended as a very efficient option in TKA.

Competing interests: the authors declare that they have no competing interests.

Funding: the authors have no support or funding to report.

References

1. Olivecrona C., Tidermark J., Hamberg P., Ponzer S., Cederfjäll C. Skin protection underneath the pneumatic tourniquet during total knee arthroplasty: A randomized controlled trial of 92 patients. *Acta Orthop.* 2006;77(3):519-523. DOI: 10.1080/17453670610012539.
2. Din R., Geddes T. Skin protection beneath the tourniquet a prospective randomized trial. *ANZ J Surg*. 2004;74(9): 721-722. DOI: 10.1111/j.1445-1433.2004.03143.x.
3. Mayer C., Franz A., Harmsen J.-F., Queitsch F., Behringer M., Beckmann J., Krauspe R., Zilkens C. Soft-tissue damage during total knee arthroplasty. *J Orthop.* 2017;14(3):347-353. DOI: 10.1016/j.jor.2017.06.015.
4. Abdel-Salam A., Eyres K.S. Effects of tourniquet during total knee arthroplasty. A prospective randomised study. *J Bone Joint Surg Br.* 1995;77(2):250-253.
5. Yi S., Tan J., Chen C., Chen H., Huang W. The use of pneumatic tourniquet in total knee arthroplasty: A meta-analysis. *Arch Orthop Trauma Surg.* 2014;134(10): 1469-1476. DOI: 10.1007/s00402-014-2056-y.
6. Guler O., Mahirogullari M., Isyar M., Piskin A., Yalcin S., Mutlu S., Sahin B. Comparison of quadriceps muscle volume after unilateral total knee arthroplasty with and without tourniquet use. *Knee Surgery, Sport Traumatol Arthrosc.* 2016;24(8):2595-2605. DOI: 10.1007/s00167-015-3872-5.
7. Rama K.R.B.S., Apsingi S., Poovali S., Jetti A. Timing of tourniquet release in knee arthroplasty. Meta-analysis of randomized, controlled trials. *J Bone Joint Surg Am.* 2007;89(4):699-705. DOI: 10.2106/JBJS.F.00497.
8. Vertullo C.J., Nagarajan M. Is cement penetration in TKR reduced by not using a tourniquet during cementation? A single blinded, randomized trial. *J Orthop Surg.* 2017;25(1):230949901668432. DOI: 10.1177/2309499016684323.
9. Verburg H., van de Ridder L.C., Verhoeven V.W.J., Pilot P. Validation of a measuring technique with computed tomography for cement penetration into trabecular bone underneath the tibial tray in total knee arthroplasty on a cadaver model. *BMC Med Imaging*. 2014;14(1):29. DOI: 10.1186/1471-2342-14-29.
10. Huang Z.Y., Pei F.X., Ma J., Yang J., Zhou Z.K., Kang P. De, Shen B. Comparison of three different tourniquet application strategies for minimally invasive total knee arthroplasty: a prospective non-randomized clinical trial. *Arch Orthop Trauma Surg.* 2014;134(4):561-570. DOI: 10.1007/s00402-014-1948-1.
11. Zhang P., Liang Y., He J., Fang Y., Chen P., Wang J. Timing of tourniquet release in total knee arthroplasty: A meta-analysis. *Medicine (Baltimore).* 2017;96(17):e6786. DOI: 10.1097/MD.0000000000006786.
12. Lee Q.J., Mak W.P., Hau W.S., Yeung S.T., Wong Y.C., Wai Y.L. Short duration and low suction pressure drain versus no drain following total knee replacement. *J Orthop Surg (Hong Kong).* 2015;23(3):278-281. DOI: 10.1177/230949901502300302.
13. Chugaev D.V., Kornilov N.N., Sorokin E.P. [Modern surgical aspects in blood loss management in total knee arthroplasty]. *Saratovskij nauchno-medicinskij zhurnal* [Saratov Journal of Medical Scientific Research] 2017;13(2):273-279. (in Russian).
14. Papalia R., Zampogna B., Franceschi F., Torre G., Maffulli N., Denaro V. Tourniquet in knee surgery. *Br Med Bull.* 2014;111(1):63-76. DOI: 10.1093/bmb/ldu012.
15. Vlasov S.V., Safronov N.F., Vlasova I.V., Tleubaeva N.V. [Risk factors of thrombohemorrhagic complications in knee joint endoprosthesis]. *Politravma* [Polytrauma]. 2009;(2):36-41. (in Russian).
16. Huang Z., Ma J., Zhu Y., Pei F., Yang J., Zhou Z., Kang P., Shen B. Timing of tourniquet release in total knee arthroplasty. *Orthopedics*. 2015;38(7):445-451. DOI: 10.1097/MD.0000000000006786.
17. Kulyaba T.A., Kornilov N.N. Artroplastika kolennogo sustava [Total knee arthroplasty]. St. Petersburg: RNIITO im. R.R. Vredena, 2012. 228 p. (in Russian).
18. Chugaev D.V., Koryachkin V.A., Kornilov N.N., Sorokin E.P. [Nonsurgical blood loss management technique in patients with total knee arthroplasty (Literature review)]. *Transfuziologija* [Transfusiology]. 2017;18(1):23-28. (in Russian).
19. Yildiz C., Koca K., Kocak N., Tunay S., Basbozkurt M. Late tourniquet release and drain clamping reduces postoperative blood loss in total knee arthroplasty. *HSS J.* 2014;10(1):2-5. DOI: 10.1007/s11420-013-9363-7.
20. Tai T.-W., Yang C.-Y., Jou I.-M., Lai K.-A., Chen C.-H. Temporary drainage clamping after total knee arthroplasty: a meta-analysis of randomized controlled trials. *J Arthroplasty.* 2010;25(8):1240-1245. DOI: 10.1016/j.arth.2009.08.013.
21. Padala P.R., Rouholamin E., Mehta R.L. The role of drains and tourniquets in primary total knee replacement: a comparative study of TKR performed with drains and tourniquet versus no drains and adrenaline and saline infiltration. *J Knee Surg.* 2004;17(1):24-27.
22. Oh C.-S., Kim S.-H., Lee J., Rhee K.Y. Impact of remote ischaemic preconditioning on cerebral oxygenation during total knee arthroplasty. *Int J Med Sci.* 2017;14(2):115-122. DOI: 10.7150/ijms.17227.

INFORMATION ABOUT AUTHORS:

Dmitry V. Chugaev — Researcher, Orthopaedic Surgeon, Trauma and Orthopaedic Department N 7, Vreden Russian Research Institute of Traumatology and Orthopedics, St. Petersburg, Russian Federation

Nikolai N. Kornilov — Dr. Sci. (Med.), Leading Researcher, Knee Pathology Department, Vreden Russian Research Institute of Traumatology and Orthopaedics, St. Petersburg, Russian Federation

Pavel G. Kogan — Researcher, Orthopaedic Surgeon, Trauma and Orthopaedic Department N 7, Vreden Russian Research Institute of Traumatology and Orthopedics, St. Petersburg, Russian Federation