MICROCIRCULATION PARAMETERS OF THE DAMAGED SEGMENT OF THE LOWER EXTREMITY AFTER TREATMENT OF DIAPHYSEAL FRACTURES USING A LOCKED INTRAMEDULLARY NAIL

Plakhov A.I. [1],
Korytov L.I. [1],
Vinogradov V.G. [1],
Darenskaya M.A. [1, 2],
Makarov S.V. [1]

[1] Irkutsk State Medical University (KrasnogoVosstaniya str. 1, Irkutsk 664003, Russian Federation)
[2] Scientific Centre for Family Health and Human Reproduction Problems (Timiryazeva str. 16, Irkutsk 664003, Russian Federation)

Corresponding author:
Alexey I. Plakhov,
e-mail: vasahplah@yandex.ru

ABSTRACT

Background. *An in-depth analysis of the scientific works of scientists and medical practitioners allows us to conclude that locked nail intramedullary osteosynthesis is the optimal and the most effective method of treating closed diaphyseal fractures of the lower leg bones, which is caused by the high stability of osteosynthesis and minimal damage to soft tissues during surgery. The processes of microcirculation changes in the early postoperative period by various metal structures, including a locked intramedullary nail, still remain unexplored. In particular, there is insufficient data on the use of a locked intramedullary nail.*

The aim of the study. *To identify the features of changes in microcirculation indices of injured lower leg bones during fixation of fragments with a locked intramedullary nail in the early postoperative period.*

Materials and methods. *The microcirculation of the lower limb segment was studied in 25 patients using laser Doppler flowmetry. Data from 25 healthy volunteers were used as a comparison group.*

Results. *It was found that in the early postoperative period, from day 1 to day 10, in patients with diaphyseal fractures of the lower leg bones operated with locked nail intramedullary osteosynthesis, there is a decrease in the cardiac range, an increase in the share of the shunt component of microcirculation compared to the nutritional share, as well as an increase in more than 1 ratio of the cardiac and respiratory range amplitude, which indicates an ischemia type of local circulatory disorder. Compensation of ischemia is done by anastomoses, since the bypass rate is increased.*

Conclusion. *In case of surgical treatment with locked nail intramedullary osteosynthesis, in the early postoperative period, an ischemic type of compensated local circulatory disorder develops. The regeneration process takes place under conditions of reduced arterial microcirculation blood flow and stable venous outflow, as well as the inclusion of anastomoses to compensate for destroyed vessels, which is associated with nail damage to the internal blood flow of the bone endosteum and intraosseous nutrient artery during the surgery.*

Key words: *microcirculation, laser Doppler flowmetry, diaphyseal fracture of the lower leg bone, locked nail intramedullary osteosynthesis*

Received: 13.12.2022
Accepted: 18.10.2023
Published: 05.12.2023

For citation: Plakhov A.I., Korytov L.I., Vinogradov V.G., Darenskaya M.A., Makarov S.V. Microcirculation parameters of the damaged segment of the lower extremity after treatment of diaphyseal fractures using a locked intramedullary nail. *Acta biomedica scientifica*. 2023; 8(5): 144-149. doi: 10.29413/ABS.2023-8.5.15

ПАРАМЕТРЫ МИКРОЦИРКУЛЯЦИИ ПОВРЕЖДЁННОГО СЕГМЕНТА НИЖНИХ КОНЕЧНОСТЕЙ ПОСЛЕ ЛЕЧЕНИЯ ДИАФИЗАРНЫХ ПЕРЕЛОМОВ С ПОМОЩЬЮ БЛОКИРУЕМОГО ИНТРАМЕДУЛЛЯРНОГО ГВОЗДЯ

Плахов А.И. [1],
Корытов Л.И. [1],
Виноградов В.Г. [1],
Даренская М.А. [1, 2],
Макаров С.В. [1]

[1] ФГБОУ ВО «Иркутский государственный медицинский университет» Минздрава России (664003, г. Иркутск, ул. Красного Восстания, 1, Россия)
[2] ФГБНУ «Научный центр проблем здоровья семьи и репродукции человека» (664003, г. Иркутск, ул. Тимирязева, 16, Россия)

Автор, ответственный за переписку:
Плахов Алексей Игоревич,
e-mail: vasahplah@yandex.ru

РЕЗЮМЕ

Обоснование. *При глубоком анализе научных трудов учёных и практикующих врачей можно прийти к выводу, что блокируемый интрамедуллярный остеосинтез является оптимальным и наиболее эффективным методом лечения закрытых диафизарных переломов костей голени, что обусловлено высокой стабильностью остеосинтеза и минимальным повреждением мягких тканей при операции. До сих пор остаются не изученными процессы изменения микроциркуляции в раннем послеоперационном периоде различными металлоконструкциями, в том числе и блокируемым интрамедуллярным гвоздём. В частности, недостаточно сведений об использовании блокируемого интрамедуллярного гвоздя.*

Цель исследования. *Выявить особенности изменений показателей микроциркуляции травмированных костей голени при фиксации фрагментов блокируемым интрамедуллярным гвоздём в раннем послеоперационном периоде.*

Материалы и методы. *У 25 пациентов с помощью лазерной допплеровской флоуметрии проведено исследование микроциркуляции сегмента нижней конечности. В качестве группы сравнения использовались данные 25 здоровых добровольцев.*

Результаты. *Установлено, что в раннем послеоперационном периоде, с 1-х по 10-е сутки, у пациентов с диафизарным переломами костей голени, прооперированных металлостеосинтезом блокируемым интрамедуллярным гвоздём, происходит уменьшение сердечного диапазона, увеличение доли шунтового компонента микроциркуляции по сравнению с нутритивной долей, а также увеличение больше 1 отношения амплитуды сердечного и дыхательного диапазона, что свидетельствует о местном нарушении кровообращения по типу ишемии. Компенсация ишемии осуществляется за счёт анастомозов, так как показатель шунтирования увеличен.*

Заключение. *При оперативном лечении блокируемым интрамедуллярным остеосинтезом в раннем послеоперационном периоде развивается нарушение местного кровообращения по ишемическому типу с компенсацией. Процесс регенерации протекает в условиях сниженного артериального кровотока микроциркуляции и стабильного венозного оттока, а также включения анастомозов для компенсации разрушенных сосудов, что связано с повреждением гвоздём внутреннего кровотока эндоста кости и внутрикостной питательной артерии в ходе операции.*

Ключевые слова: *микроциркуляция, лазерная допплеровская флоуметрия, диафизарный перелом голени, блокируемый интрамедуллярный остеосинтез*

Статья поступила: 13.12.2022
Статья принята: 18.10.2023
Статья опубликована: 05.12.2023

Для цитирования: Плахов А.И., Корытов Л.И., Виноградов В.Г., Даренская М.А., Макаров С.В. Параметры микроциркуляции повреждённого сегмента нижних конечностей после лечения диафизарных переломов с помощью блокируемого интрамедуллярного гвоздя. *Acta biomedica scientifica*. 2023; 8(5): 144-149. doi: 10.29413/ABS.2023-8.5.15

INTRODUCTION

It has been established that in the structure of bone fractures of all localisations, tibia fractures are predominant (ranging from 20 to 37.3 %); they also account for up to 60 % of the total number of fractures of long bones [1].

A deep analysis of the scientific works of scientists and practicing physicians leads to the conclusion that locked intramedullary osteosynthesis (LIOS) is the optimal and most effective method of restoring bone integrity in closed diaphyseal fractures of the tibia, which is caused by high stability of osteosynthesis and minimal damage to soft tissues during surgery [1, 2]. The fundamental reason for the development of various complications in the treatment of traumatological diseases is a violation of microcirculatory processes in the damaged extremity segment. As is well known, the above-mentioned soft tissue injuries are possible both during direct trauma and during surgical intervention; accordingly, the more serious the volume of surgical intervention, the deeper the soft tissue injuries the patient receives. It is essential to correct local tissue microcirculation disorders in the area of the affected extremity, as high-quality haemodynamics is essential for restoring the viability of damaged tissues, their subsequent regeneration and the course of inflammation [3, 4].

Consequently, an objective recording of the microcirculation disorders manifestations is necessary for effective recovery after surgery, which will allow noninvasively determining the state of local microcirculation disorders in the tissues of the affected extremity [3, 4].

Laser Doppler flowmetry (LDF) is one of the unique highly sensitive and non-invasive methods providing wide diagnostic possibilities in the study of microcirculation disorders [5]. The LDP method, according to the research data of domestic and foreign literature, allows to determine quite accurately various links of microcirculatory channel disorders and to determine quite accurately the development of pathophysiological processes in extremities [6]. However, the processes of microcirculation changes after surgical treatment of extremity bone fractures in the early postoperative period with various metal structures, including intramedullary locking nail, remain to be studied. In particular, there is insufficient information about the use of the method of surgical treatment of tibia bone fractures in the diaphysis area using an intramedullary locking nail, which predetermined the purpose of this study.

THE AIM OF THE STUDY

To reveal the peculiarities of changes in the microcirculation indices of traumatized tibia bones during fragment fixation with intramedullary locking nail in the early postoperative period.

MATERIALS AND METHODS

This study was conducted on the basis of Irkutsk City Clinical Hospital No. 3 in 2014–2016. The data describing the microcirculation in the main group consisting of 25 patients being under treatment in a trauma hospital were recorded and carefully analyzed. The study group was formed by the continuous sampling method. The criteria for entering the group were: being in a trauma hospital; age up to 59 years; and primary trauma to the tibia bones. The exclusion criteria for the study were described in a previous study [6]. The examined patients differed in the severity of injuries (Table 1). All patients on admission with closed diaphyseal fractures of the tibia bones underwent preliminary skeletal traction. After further examination, the patients underwent surgery aimed at matching the broken bone fragments – closed repositioning followed by an intraosseous metal osteosynthesis using an intramedullary locking nail. The same conventional drug therapy including disaggregants, antibacterial agents, and topical drug therapy, etc. were used in the whole group of patients during treatment. The surgical access site was also treated and dressed (Table 1).

TABLE 1

DISTRIBUTION OF PATIENTS ACCORDING TO THE NATURE OF FRACTURES AND THEIR LOCALIZATION (ACCORDING TO THE AO/ASIF CLASSIFICATION)

Number of patients	42A1	42A2	42B1	42C1	Total
abs.	16	1	4	4	25
%	64 %	4 %	16 %	16 %	100 %

Patients with tibial diaphysis fractures according to the AO/ASIF (Albeitgemeinshaft fur Osteosynthenfragen/Association for the Study of Internal Fixation) classification of group 42A1 (64 %) made up the largest group of the study population.

The clinical comparison group consisted of 25 healthy volunteers statistically significantly comparable in age and sex.

Experimental study of microcirculatory parameters indices was performed using a non-invasive LDF method with the LAKK-OP device (version 2) (SPE "Lazma", Russia). The advantages and operation mechanisms of this analyser are more detailed discussed in the previous articles devoted to this subject [6, 7].

LDF-diagrams were recorded for at least 10–11 min, with the transducer placed on the dorsal surface of the foot in the projection of the proximal part of the 1st metatarsal bone of the injured extremity. The microcirculation index (M) was assessed; a specific feature of this device is also

the registration of additional narrowly focused parameters, such as: shunt index (SI), maximum amplitudes of cardiac (Ah) and respiratory (Ar) oscillation ranges.

LDF diagnostics was performed at the same time of day, at the same room temperature (21–23 °C). Before the microcirculation study, the examinees did not ingest food or liquids, did not smoke, and did not assume an upright position.

All studies were performed in the early postoperative period, from the day 1 to the day 10 on daily basis. Based on the shunt index (SI) and microcirculation, the shunt component of the microcirculation index (M shunt.) and nutritive microcirculation index (M nutr.) were determined using the same formulas as in the previous study [7].

The cumulative analysis of the obtained data is the optimal study of microcirculation, since the isolated assessment of one of the parameters does not give a complete picture of the ongoing pathophysiological processes [8]. Thus, for a comprehensive complete and objective study in LDF-diagnostics of local disorders of microcirculatory processes the index of microcirculation, including the state of oscillatory processes associated with arterial inflow (Ah) and venous outflow (Ar) is of great importance.

It was obligatory for patients to sign informed consent to participate in the study in accordance with the ethical principles of the World Medical Association Declaration of Helsinki (1964, 2013 ed.). The study was approved by the Ethical Committee of the Irkutsk State Medical University (extract from minutes No. 2 dated April 16, 2014).

For the purpose of statistical data processing, MS Excel 2010 (Microsoft Corp., USA) and Statistica 10.0 for Windows (StatSoft Inc., USA) software were used. Based on the distribution of data, non-parametric (Mann – Whitney) or parametric (Student's t-test) criteria were used in the analysis. The data obtained were summarized using median, 25th and 75th percentiles or mean values and standard deviation.

RESULTS AND DISCUSSION

In this study we will dwell in more detail on the local blood circulation disorders using the interpretation of the laser Doppler flowmeter LAKK-OP (version 2) (NPP "Lazma", Russia).

Table 2 summarizes the studies of the clinical comparison group and the main group.

The study revealed that the microcirculation index had no statistically significant difference between the patients of the main group who underwent LIOS surgery and the clinical comparison group in the early postoperative period (days 1–10). These findings indicate local circulatory disorders of the compensatory ischaemia type. The experiment also revealed that the ratio of the proportions of the shunt and nutritive components of the microcirculation indices evidenced the violation of local circulatory disorders of ischaemic type, and the proportion of the shunt component compared to the nutritive component was 18.32 % higher.

An important point to be noted is that a striking parameter confirming the presence of ischaemia is a 39.01 % decrease in cardiac range amplitude (Ah) in the main group compared to the clinical comparison group.

No statistically significant difference was revealed when interpreting the respiratory range amplitude (Ad) amplitude parameters, indicating the absence of congestion and compensation of the ischaemic form as a result of the processes discussed further.

The ratio of heart rate and respiratory amplitude is unequivocally greater than 1 in the main group, which also evidences the existence of ischaemia [8].

TABLE 2

MICROCIRCULATION PARAMETERS IN THE MAIN AND THE COMPARISON GROUPS

Parameters	Main group		Clinical comparison group	
	I	II	III	IV
M	5.86 (5.77–6.37)	5.95 ± 0.33	6.46 (5.2–8.38)	6.72 ± 2.26
SI	2.27 (1.39–1.76)×	2.45 ± 0.36×	1.65 (0.83–2.04)×	1.57 ± 0.32×
The proportion of M nutr.	2.43	2.43	–	–
The proportion of M shunt.	3.52	3.52	–	–
Ah	0.15 (0.11–0.16)×	0.14 ± 0.01×	0.23 (0.19–0.28)×	0.24 ± 0.04×
Ar	0.11 (0.10–0.13)	0.11 ± 0.01	0.13 (0.1–0.16)	0.13 ± 0.02
Ah/Ar	1.26	1.26	–	–

Note. Data from the first (I) and third (III) columns are presented as median with lower and upper quartiles (25th and 75th percentiles); data from the second (II) and fourth (IV) columns are presented as mean values and standard deviation; × – statistically significant differences between groups ($p < 0.05$).

A statistically significant increase of 56.1 % in the shunt rate in the main group reveals the inclusion of shunt vessels and evidences the significant role of shunts in compensating ischaemia to restore blood circulation within the bone, since during surgery, the nail being inserted disrupts blood flow in the endosteum, which is not contrary to the basic study "Bone Regeneration and Blood Supply" [9].

We hypothesize that LIOS is followed by destruction of endosteal internal blood flow during surgery, after which the arterial supply to the operated extremity is impaired. This change is registered by a 39.01 % decrease in heart range amplitude (Ah). The other parameters confirming ischaemia in the injured extremity include such parameters as the proportion of shunt component of microcirculation compared to nutritive component, increased by 18.32 %, and increase in the ratio of heart to respiratory range amplitude greater than 1. This is followed by additional mechanisms that activate anastomoses or shunts, causing the values of the shunt index parameter to be 56.1 % higher than those of the clinical comparison group (healthy individuals). As a result, the blood circulation of the injured extremity is replenished, which is reflected by the value of the microcirculation index (M), which is not statistically significantly different from that in the clinical comparison group. No circulatory stasis was also observed, as the amplitude of respiratory range of variation (Ar) was not statistically significantly different from that of the clinical comparison group.

Considering the wide variety of obtained indicators of microcirculatory disorders, a compensatory ischaemia type of local blood circulation was revealed. These values indicate a decrease in arterial blood inflow to the extremity, which is associated with damage to the bone endosteum and intraosseous feeding artery by the internal blood flow nail during the surgery with subsequent compensation of ischaemia by including anastomoses, since during this surgery there is minimal damage to soft tissues and periosteum, and there is no surgical access at the fracture site, due to which the deficit of blood supply to the extremity is levelled, and the healing process is accompanied by a stable venous outflow of blood throughout the entire study period.

CONCLUSION

According to the present study, it was revealed that patients with diaphyseal fracture of the tibia bones who underwent surgery with an intramedullary locking nail have a compensated ischaemic-type circulatory disturbance in the injured extremity in the early postoperative period. Consequently, tissue regeneration occurs under conditions of reduced arterial blood flow, decreased microcirculation and normalized venous outflow caused by the inclusion of anastomoses to compensate for the destroyed vessels, which seems to be related to the nail damage of the internal blood flow to the bone endosteum and intraosseous feeding artery during surgery.

Conflict of interest

The authors of this article confirm that there is no conflict of interest.

REFERENCES

1. Martynenko NP. Practical experience in the treatment of fractures of the distal and proximal tibia metadiaphysis by locking intramedullary osteosynthesis. *Science & Healthcare*. 2014; (2): 114-115. (In Russ.). [Мартыненко Н.П. Практический опыт лечения переломов дистального и проксимального метафизов большеберцовой кости методом блокирующего интрамедуллярного остеосинтеза. *Наука и здавоохранение*. 2014; (2): 114-115].

2. Kavalerskiy GM, Yakimov LA, Kashcheev AA, Kalinskiy BM, Donchenko SV, Kalinskiy EB, et al. Technique of reduction and intramedullar nailing of distal metaphyseal fractures with intraoperative hybrid external fixation. *The Department of Traumatology and Orthopedics*. 2015; (2): 4-7. (In Russ.). [Кавалерский Г.М., Якимов Л.А., Кащеев А.А., Калинский Б.М., Донченко С.В., Калинский Е.Б., и др. Применение способа интраоперационной репозиции и интрамедуллярного остеосинтеза переломов дистального метафиза большеберцовой кости. *Кафедра травматологии и ортопедии*. 2015; (2): 4-7].

3. Kolesnikova LI, Rychkova LV, Kolesnikova LR, Darenskaya MA, Natyaganova LV, Grebenkina LA, et al. Coupling of lipoperoxidation reactions with changes in arterial blood pressure in hypertensive ISIAH rats under conditions of chronic stress. *Bulletin of Experimental Biology and Medicine*. 2018; 164(6): 712-715. doi: 10.1007/s10517-018-4064-3

4. Shemyakina NA, Namokonov EV, Darenskaya MA, Kolesnikov SI, Kolesnikova LI. Advanced glycation end products and glutathione status in patients with type 2 diabetes mellitus and macroangiopathy of the lower limbs. *Free Radic Biol Med*. 2018; 120(1): 60-61. doi: 10.1016/j.freeradbiomed.2018.04.200

5. Miromanov AM, Mironova OB, Uskov SA, Namokonov EV, Shapovalov KG. Dynamics of indicators of microcirculation and components of the vascular tonus at patients with the uncomplicated and complicated course of fractures of long tubular bones in the early postoperative period. *Siberian Scientific Medical Journal*. 2011; 31(3): 12-17. (In Russ.). [Мироманов А.М., Миронова О.Б., Усков С.А., Намоконов Е.В., Шаповалов К.Г. Динамика показателей микроциркуляции и компонентов сосудистого тонуса у больных с неосложненным и осложненным течением переломов длинных трубчатых костей в раннем послеоперационном периоде. *Сибирский научный медицинский журнал*. 2011; 31(3): 12-17].

6. Plakhov AI, Vinogradov VG, Angarskaya EG. The use of laser Doppler flowmeters in traumatology. *Siberian Medical Journal (Irkutsk)*. 2015; 138(7): 52-56. (In Russ.). [Плахов А.И., Виноградов В.Г, Ангарская Е.Г. Использование лазерных допплеровских флоуметров в травматологии. *Сибирский медицинский журнал (Иркутск)*. 2015; 138(7): 52-56].

7. Plakhov AI, Kolesnikova LI, Korytov LI, Vinogradov VG, Darenskaya MA. Changes in indicators of microcirculation in the early postoperative period in the treatment of diaphyseal fractures of the shin bones using a plate with limited contact. *Acta biomedica scientifica*. 2019; 4(3): 58-62. (In Russ.). [Плахов А.И., Колесникова Л.И., Корытов Л.И., Виноградов В.Г., Даренская М.А.

Изменения показателей микроциркуляции в ранний послеоперационный период при лечении диафизарных переломов костей голени с помощью пластины с ограниченным контактом. *Acta biomedica scientifica.* 2019; 4(3): 58-62]. doi: 10.29413/ABS.2019-4.3.8

8. Krupatkin AI, Sidorov VV. *Functional diagnostics of the state of microcircular tissue systems: A guide for physicians.* Moscow, 2013. (In Russ.). [Крупаткин А.И., Сидоров В.В. *Функциональная диагностика состояния микроциркулярно-тканевых систем: Руководство для врачей*. М., 2013].

9. Lavrishcheva GI, Karpov SP, Bachu IS. *Bone regeneration and blood supply.* Kishinev; 1981. (In Russ.). [Лаврищева Г.И., Карпов С.П., Бачу И.С. *Регенерация и кровоснабжение кости.* Кишинев; 1981].

Information about the authors

Alexey I. Plakhov – Postgraduate, Orthopedic Traumatologist, Irkutsk State Medical University, e-mail: vasahplah@yandex.ru, https://orcid.org/0009-0006-6380-5086

Leonid I. Korytov – Dr. Sc. (Med.), Professor at the Department of Normal Physiology, Irkutsk State Medical University, e-mail: korytovli@yandex.ru, https://orcid.org/0000-0003-1500-8219

Valentin G. Vinogradov – Dr. Sc. (Med.), Professor, Professor at the Department of Traumatology and Orthopedics, Irkutsk State Medical University, e-mail: vinogradov.travma@gmail.com, https://orcid.org/0000-0002-6470-3800

Marina A. Darenskaya – Dr. Sc. (Biol.), Senior Lecturer at the Department of Normal Physiology, Irkutsk State Medical University; Leading Research Officer at the Laboratory of Pathophysiology, Scientific Centre for Family Health and Human Reproduction Problems, e-mail: marina_darenskaya@inbox.ru, https://orcid.org/0000-0003-3255-2013

Sergei V. Makarov – Cand. Sc. (Med.), Docent, Associate Professor at the Department of Public Health and Healthcare, Irkutsk State Medical University, e-mail: orgnursing@gmail.com, https://orcid.org/0000-0001-8364-5223

Authors' contribution

Plakhov A.I. – collection of practical material; processing of the obtained data; preparation of the article for publication.

Korytov L.I. – editing of the article; preparation of the article for publication; analysis of study results.

Vinogradov V.G. – scientific supervision for the postgraduate student; discussion of clinical material and significance for practical healthcare.

Darenskaya M.A. – assistance in statistical processing of the obtained results.

Makarov S.V. – assistance in statistical processing of the obtained results.