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CONTENTS

Integration of virtual reality into the program of non-drug treatment of pain and early rehabilitation

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Abstract. The article deals with the issues of non-drug treatment of pain from the standpoint of a biopsychosocial approach using virtual reality (VR), as well as the possibility of integrating this method into an early rehabilitation program for neurological patients. The historical aspects of discovery and integration of VR into medicine and the results of using the method to reduce the intensity of pain in patients with burn disease, the possibility of using VR technology in anesthesiology and resuscitation as an alternative to narcotic analgesics for certain types of intervention are presented. The use of VR is promising in the motor and cognitive rehabilitation of patients with various pathologies of the central nervous system and can be used at any stage of rehabilitation, at low financial costs, with minimal involvement of medical personnel in the hospital and outpatient settings.

Keywords: virtual reality, pain, theories of pain, biopsychosocial approach, stroke, rehabilitation.

Introduction. One of the most pressing medical problems of our time remains the treatment of acute and chronic pain syndrome, as well as the need for early comprehensive rehabilitation of this category of patients to improve disease outcomes and quality of life. The prevalence of pain syndrome in the world population varies from 10 to 85% depending on the disease that accompanies the pain [1, 2]. In the case of malignancies chronic back pain and postoperative pain, depending on the stage and severity of the process, the pain syndrome is registered in 35-96% of patients [3, 4]. The widespread prevalence of this problem and the limited range of treatment options in the form of narcotic and non-narcotic analgesics, many of which have side effects and complications, led to the need to search for non-medicinal alternative methods of pain treatment. Due to the fact that today's world is becoming more and more computerized, and technological progress and modern computer technologies are quickly integrated into the sphere of medicine, it is consequential to develop and use virtual technologies as one of the tools for the treatment of pain. The developers of VR-technology believe that their use will help to reduce the number of opioid medications used, and, therefore, reduce the rates of dependence on them [5]. The largest studies in this field are devoted to the rehabilitation of neurological patients, mainly with acute impairment of cerebral circulation (AICC), which is associated with a high prevalence of pain syndrome, cognitive and motor impairments. This contingent needs the use of quick and effective methods of recovery [6].

Purpose. To search and analyze the national and foreign literature, which presents various studies on the use of VR for either the treatment or reduction of pain syndrome intensity, and as part of early rehabilitation of predominantly neurological patients. The PubMed and Elibrary databases were searched for the period 2011-2021. The following search terms were used: "pain", "pain syndrome", "AICC", "multiple sclerosis", "rehabilitation", "virtual reality", "pain", "stroke", "early rehabilitation", "virtual reality", "virtual reality for pain reduction", "virtual reality for stroke rehabilitation". The analysis includes 1 article from 2011, 1 article from 2015, and 51 publications from 2016-2021.

Treatment of pain in burn patients — the first experience of virtual reality application in medicine. The use of VR technology in the medical field has been on the minds of scientists since the early 90s of the 20th century. The most well-known works in this direction belong to Hunter Hoffman and David Petterson, who studied the impact of VR systems on patients' attention during certain manipulations. A breakthrough in scientific research can be considered their creation in 1996 of a system to reduce the intensity of pain during bandaging in burn patients, which has a peculiar name "Snow World". [7]. Researchers have found that the intensity of pain perception is related to the patient's mental functions, namely attention. In particular, when dressing burn wounds, the patient concentrates on this manipulation, so that the pain is perceived more intensely, up to intolerable, which required bandaging under general anesthesia, which has its negative consequences. To reduce the intensity of pain and avoid anesthesia during dressings, an alternative method is needed to distract the patient during the procedure, which means to switch his attention by various ways, for example, by music or movies. VR works on the same principle, but in case of its application, it is possible to achieve a more pronounced effect [8].

To reduce the intensity of pain and avoid anesthesia during dressings, an alternative method is needed to distract the patient during the procedure, which means to switch his attention by various ways, for example, by music or movies. VR works on the same principle, but in case of its application, it is possible to achieve a more pronounced effect. If we consider the mechanism of virtual reality functioning in terms of modern theories of pain, we see the realization of the biopsychosocial concept of pain treatment

The patient is fitted with a special helmet and noise-canceling headphones in the form of music, which allows him to "disconnect" from the real world. An image is transmitted through the screens in the helmet. The patient is "immersed" into the space and game, where he is surrounded by giant drifts, penguins, snowmen — the characters of the VR game "Snow World". The patient is tasked to travel through the snowy expanses, throwing snowballs at penguins and other characters by pressing the computer mouse [7], so that his attention completely shifts from the painful dressing procedure to the task of

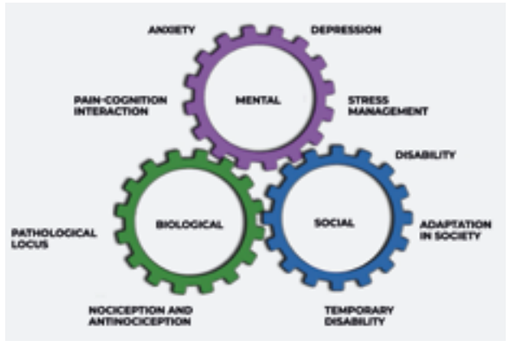

Fig. 1. The biopsychosocial concept of pain

the VR game. If we consider the mechanism of virtual reality functioning in terms of modern theories of pain, we see the realization of the biopsychosocial concept of pain treatment (Fig. 1).

This model is based on integration of three major factors: organic (presence of pathological locus, as well as activation of nociceptive and antinociceptive systems), social (temporary disability, disability, socialization difficulties) and psychological, conditioned by individual emotional and behavioral reactions of a person (depression, anxiety, pain-congnition interaction, coping with stress). All the above factors affect each other, increasing or decreasing the intensity of pain perception in each case [9, 10].

Virtual reality works at the intersection of the biological and psychological components of this concept. The effect of this system is associated with the formation of a new dominant in the cerebral cortex, which is a more powerful stimulus and suppresses the already existing focal point of pain perception. As a result, the patient, fully immersed in the VR game, does not experience painful sensations from the bandaging procedure carried out at this time (Fig. 2) [11]. It was also found that the "Snow World" works not only at the level of switching the patient's attention, but is also connected with a certain amount of positive self-hypnosis: seeing snow around him, the patient perceives this space as real, and he has a feeling that the temperature on the burned surface has dropped, which alleviates his condition [7]. This technology has been used for more than twenty years in burn centers in the United States, Australia and Israel. Recent studies of the effectiveness of this program have found that patients using virtual reality during bandaging have about five times less need for opioid analgesics than without it (11% with VR versus 60% without this technology) [12]. Patients also note a decrease in the intensity of pain syndrome after using a virtual reality session [13].

The effectiveness of virtual reality for different types of pain. The great success of "Snow world" has been the impetus for further scientific research and the development of new programs for the treatment of acute and chronic pain of various etiologies. In studies using VR in patients in the postoperative period over a 6-month period, two groups of patients were compared: the 1st group used a VR game that required throwing balls at targets with 360° motion for 14 minutes, while the 2nd group watched health video clips at the same time. In total, more than 50 postoperative patients took part in the trial. A decrease in the intensity of pain syndrome was shown in 65% of subjects in the VR group, while in the control group the figure was 40% [14]. However, studies of VR in patients after hemorrhoidectomy have shown that pain reduction in any case will be insignificant, and still requires the use of standard medications [15], so we cannot reliably confirm the versatility of this method for various surgical interventions, and the issue of its application must be decided individually.

The use of VR in the management of chronic pain is considered more seriously by specialists, due to its association with the permanent administration of medication with common side-effects [16]. Numerous studies demonstrate that the use of 5-minute virtual reality sessions, including at home, has contributed to the complete disappearance of pain in about 33% of patients, and up to 100% of patients report a reduction in pain intensity while using the program [17].

Ongoing research in patients with chronic back pain have demonstrated that when VR was used in these patients during therapeutic exercise used as a means of rehabilitation, there was a significant reduction in pain intensity relative to the control groups. Accordingly, in one study, patients were divided into two groups of 42 people each: the first played two VR-games in a row, in which using the movements of the pelvis was necessary to either lead a caterpillar through a sequence of hoops floating in the air, or help the fish to get from one end of the cave to the other, without hitting the walls and other fish. At the same time, the control group performed the same movements, but without visual support. Patients were guided only by a short sound signal that signaled the need to change body position at different intervals. It was found that the participants who used VR performed more actively and reported a decrease in pain, while the patients in the control group showed less satisfactory results, which was due to the inability to distract themselves from pain as a result of high concentration on the given task [18, 19]. The combination of VR-technology has also been shown to be more effective in exercising as part of the treatment of chronic cervical spine pain, as it helped not only to reduce the intensity of pain after 3 months of therapy, but also to get rid of kinesiophobia in this category of patients [20, 21].

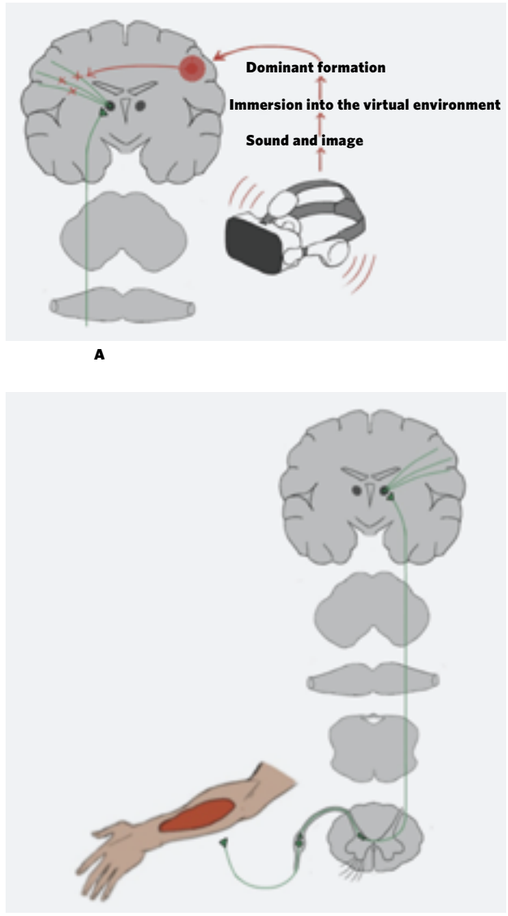

Fig. 2. Propagation of the pain impulse during a burn and the point of application of virtual reality

Virtual reality as an alternative to anesthesia in patient examinations. Many medical manipulations performed for the purpose of examination of a patient involve the development of pain syndrome and require the use of anesthetic medication. This is particularly true for some types of endoscopic examination [22]. For instance, the use of VR technology in more than 40 women at the time of hysteroscopy has demonstrated a significant reduction in pain, as well as a reduction in anxiety and stress levels associated with the procedure. Some patients have positively rated the fact that the VR helmet prevents them from seeing the doctor and instruments, which under normal circumstances would cause them additional anxiety. It should be noted that the women do not talk about the complete disappearance of pain, but about a significant reduction in its intensity, as well as the possibility of shifting attention from episodes of acute pain to pleasurable images in VR space. Only 10% of patients needed standard analgesia [23]. The same result was achieved by researchers comparing more than 60 patients undergoing colonoscopy with and without VR, which somehow favors the use of VR as an alternative method of anesthesia for these procedures [24].

Of particular note is the use of various VR programs during cubital vein sampling for laboratory examination in children. In numerous trials, each of which examined groups of between 40 and 120 children aged between 6 and 16 years, it was found that this method of distraction significantly reduced the risk of a marked response to a painful trigger and the level of anxiety. A higher proportion of children demonstrated lower pain scores on the visual analogue scale after VR than without it [25].

Application of virtual reality technology in the rehabilitation of neurological patients. Neurologists have paid attention to the perspectives of VR-technology application, due to the fact that while the treatment of organic lesions of the nervous system is at a fairly high level, the rehabilitation of patients at various stages requires further improvement. Virtual reality, unlike traditional methods, provides the patient with the necessary space to form biofeedback pathways, as well as due to the game form causes increased motivation for treatment and reduces stress levels [26, 27]. Rehabilitation programs in neurology are divided into 3 groups according to the need to fill deficits (motor, cognitive, sensory or coordination): training motor skills, cognitive functions or correcting emotional state. The first group makes it possible for the patient to return to daily physical activities as soon as possible. Through the use of VR technology, impaired motor skills in the upper limbs, gait and balance can be reduced or eliminated. The other programs can help patients quickly regain social skills and successfully return to an active life in society. The peculiarity of virtual reality is an infinite number of reproductions of a specific scenario set specifically for the patient, taking into account his disease, the severity of his condition and his capabilities (Fig. 3) [28, 29].

Thus, the use of VR technology is promising in the motor and cognitive rehabilitation of patients with various central nervous system pathologies, and can be used at any stage of rehabilitation, at low financial cost, with minimal involvement of medical personnel in hospital and outpatient settings [30].

There is currently available data on the successful use of VR in the rehabilitation of patients after AICC, multiple sclerosis, cerebral palsy, stroke, Parkinson's disease, Down syndrome, autism spectrum disorders,

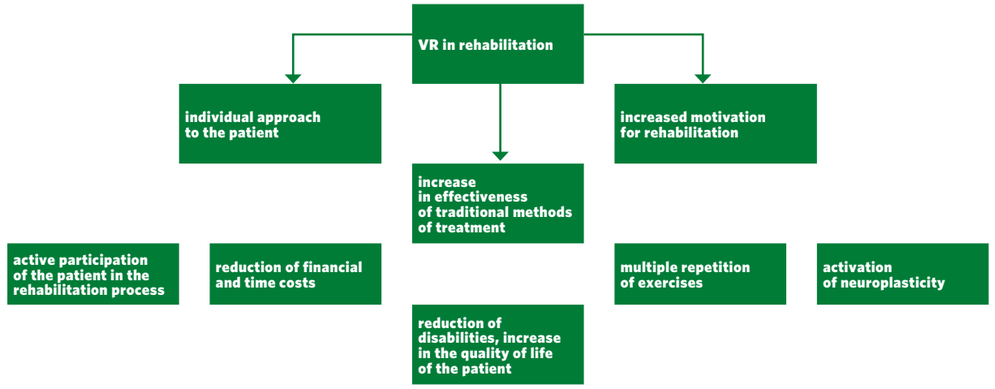

Fig. 3. Virtual reality action in patient rehabilitation

schizophrenia and dementia [31-33]. The use of VR in patients with brain and spinal cord injury has been less studied due to the marked heterogeneity and small size of the study population, but small studies have shown positive results, including children [34, 35].

In order to create a state of emotional comfort and increase patient involvement in the rehabilitation process, playful and domestic scenarios are often used: cooking, playing ball, shooting at targets, tending flowers, catching "falling" objects [36, 37]. The most commonly used platforms are the «Nintendo Wii Fit, the Microsoft Xbox 360 Kinect», mainly for balance training, and the «Kinect Sensor» and «Leap Motion Controller», specializing in limb motion capture and fine motor hand tracking [38-42].

Virtual reality in the early rehabilitation of patients with acute cerebral hemorrhage. There is a notion that early neurocognitive intervention decreases the likelihood of long-term consequences in patients with AICC. This is confirmed by functional magnetic resonance imaging studies, which indicate that interventions are most effective precisely in the early post-stroke period. However, the rehabilitation methods used are not always accessible, but costly and time-consuming [43]. Especially significant for this group of patients is the restoration of motor function in the limbs affected by hemiparesis through the activation of neuroplasticity and cortical reorganization. VR technology can be used for this purpose. The use of VR has been reported to accelerate the recovery of muscle strength, speed and range of motion of the paretic upper limb, decreasing the risk of complications such as muscle atrophy, osteoporosis and spasticity [44-46]. Muscle training of the limbs is mostly done in a playful format. For example, in one South Korean study, the use of a canoeing simulator was demonstrated to significantly improve muscle function and balance in post-stroke patients. Interaction with the VR system took place under conditions of visual simulation of the environment and real "paddle" movements. The experimental group of 15 people demonstrated 27.7% higher performance than before the VR game and 11% higher than a similar control group [47].

It has been demonstrated that the use of VR-technology in simulation of walking with the use of special simulators increases the effectiveness of traditional methods of rehabilitation in patients with lower limb dysfunction due to the formation of biofeedback [48]. However, there is the practice of combining a helmet or VR-glasses creating the required environment and a treadmill on which the patient navigates through a programmable space. The use of virtual reality in cognitive rehabilitation has improved memory, accelerated thinking, and normalized the psycho-emotional state of patients with AICC compared to conventional methods [49]. Patients treated with VR reported greater satisfaction with therapy and a high level of motivation for treatment. The use of VR in the acute period of stroke allows to provide a certain amount of physical and cognitive activity, which improves cerebral blood flow, promotes the activity of neurotransmitters and formation of new neural connections, leading to positive results, improving the mood of patients and influencing the further course of recovery of impaired functions (Fig. 4) (44).

It has been noted that even with a late start in rehabilitation, the use of VR remains effective. In a study involving 54 people with mild lesions aged from 20 to 81 years, where virtual reality was used to train fine motor skills of the hands, the basic indicators recovered better [50].

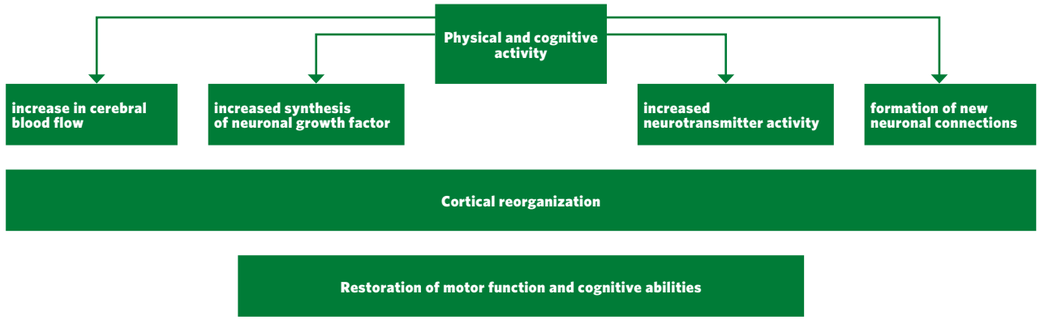

Fig. 4. Effects of virtual reality in acute impairment of cerebral circulation

Among the negative effects of using VR are dizziness, nausea, pain in the cervical spine, and negative emotions when failing. Also, in rehabilitation programs, the question of the load, intensity, and duration necessary to obtain a guaranteed clinical result has not yet been studied.

Thus, it can be stated that the benefits of using virtual reality in comprehensive rehabilitation programs are much higher than the stated VR risks. The program is characterized by safety, efficiency, low cost, and most importantly, the possibility of an individual approach to each patient.

Conclusion. The search for effective and safe methods of pain management and early rehabilitation should be fundamental to the work of medical personnel in order to improve patients' quality of life and disease prognosis.

Virtual reality as one of the most modern and high-tech means for several decades already shows its effectiveness within the framework of solving the above-mentioned issues. This method can be considered as an alternative to treatment with opioid and non-opioid analgesics, which will significantly reduce the risks of adverse reactions in patients with chronic pain syndrome.

Virtual Reality facilitates accelerated recovery of motor and cognitive impairment in post-stroke patients, being the most cost-effective and simple tool for rehabilitation in this category of patients.

Immersion in a virtual environment increases treatment motivation and reduces stress levels, which is beneficial for the effectiveness of the therapy.

The introduction of this technology in our country should be strongly considered in both inpatient and outpatient care in order to improve treatment outcomes and increase patient compliance.

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Polymer biodegradable fixators in the treatment of near- and intra-articular fractures

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Abstract. We have observed an increase in the number of patients with intra-articular fractures, as well as in the severity of such fractures. Traditionally, metal implants such as wires, capless screws, Herbert screws are used for osteosynthesis of intra-articular fractures with small bone and cartilage fragments. However, the metal implants have their drawbacks. Biodegradable fixatives (BDF) made from a copolymer of polylactic and polyglycolic acids (PLGA) could be an alternative to the implants.
Two groups of 132 people with intra-articular fractures of different localization were formed, biodegradable implants were used in the main group, metal implants were used in the control group. The groups were correlated by sex, age and nature of fractures. We compared the time spent in the operating room for similar operations, the number of operations to remove the fixators in both groups, and the number of complications. Compared functional outcomes. We assessed the possibility of interpreting MSCT and MRI data in the isolated use of BDF.
In the group with the use of biodegradable implants, fewer removal operations were required (44%) than in the group without the use of biodegradable implants (58%), which is statistically significant. Complications developed in the main group amounted to 3% (4 cases), while in the group with metal implants they amounted to 10% (13 cases).
We have found that the use of biodegradable implants has satisfactory clinical results, a low percentage of implant removal operations, and lower complications rate.

Keywords: biodegradable implants, intraarticular fractures, surgical treatment, polylactic acid, polyglycolic acid.

Introduction. According to our data, approximately one third of patients in the trauma department are patients with intra-articular fractures. In recent years, there has been an increase in the number of such fractures and their severity. This is associated with increased physical activity in the elderly and increased life expectancy, since bone quality deteriorates with age [1-3]. In the younger generation it is caused by the increasing popularity of extreme sports [4].

When treating intra-articular fractures, it is necessary to perform minimally traumatic fracture repositioning, achieve congruence of articular surfaces, then stably fix the fracture and ensure early mobilization of the limb to restore joint function [5]. Sometimes, surgical treatment of intra-articular fractures is difficult due to their splintering nature, low density of cancellous bone in the fracture area, and the need for precise restoration of the articular surface. Another problem in the treatment of intra-articular fractures is the fragmentation of the articular surface with the presence of free fragments. Disongruent articular surfaces or cartilage defects increase the risk of posttraumatic arthritis and contractures, resulting in reduced quality of life. Metal spokes, Herbert screws, and small-diameter screws are used to fix small osteochondral fragments between themselves or directly through cartilage [6, 7]. Metal fixators in this situation have a number of disadvantages: spokes are prone to migration; screws and spokes can deform and break when reinjured, when early movements in the joint are initiated [8-10]; they can become an obstacle during subsequent operations, for example, in joint endoprosthetics [11]; they interfere with interpretation of CT and MRI data, due to distortion [12]. The presence of steel fixators by some manufacturers is a contraindication for MRI or requires limiting the magnetic field power of the device [13]. Sometimes patients insist on implant removal due to psychological discomfort caused by the presence of a metal object in the body. At times, the surgery to remove the fixator is more difficult than the preceding osteosynthesis surgery.

As an alternative to metal fixators, polymeric biodegradable screws and pins made of polylactic and polyglycolic acid (PLGA) and their copolymers can be used. These implants are free of many problems that are created by traditional metal fixators [14-16].

Purpose. To determine the effectiveness of polymeric biodegradable fixators (BDF) in osteosynthesis of peri- and intra-articular fractures by summarizing the experience of their use and comparing them to conventional osteosynthesis with metal implants.

Material and Methods. We used biodegradable fixators (BDF) made from L-lactide-co-glycolide copolyme (PLGA) in an 85:15 ratio as alternative implants. Material and Methods. We used L-lactide-co-glycolide copolymer (PLGA) BDFs in an 85:15 ratio as alternative implants. After embedding in the bone, they are resorbed by hydrolysis (with the formation of water and carbon dioxide) within 2 years and retain mechanical strength for 8 weeks. This combination of copolymers represents an optimal balance of strength and biodegradation time. Biodegradable fixators have the familiar design of both full-threaded and partial-threaded screws. For controlled insertion the screws can be cannulated (Fig. 1). The pins are a rod with longitudinal ribs on the surface, which allows them to be firmly fixed in the canal and prevents their migration from the bone (Fig. 2). After insertion, biodegradable implants swell, increasing in volume by 2%, and shorten by 2%, which leads to interfragmental compression — the so-called self-compression effect.

We have been using polymeric fixators since 2014. During the period 2014-2021, 132 patients with various fractures were underwent surgical treatment, 63 (48%) of them were men and 69 (52%) were women. These patients made up the study group. The mean age of the patients was 42 (30; 56) years, ranging from 20 to 68 years. Biodegradable fixators were used both in isolation and in combination with metal implants. The indications for isolated use were tibial plateau fractures of type I according to J. Schatzker (1979) [17] (Fig. 3), type III fractures according to J. Schatzker (Fig. 4), osteochondral fractures of the femoral condyles (Fig. 5), type II fractures of the head of the radius by Mason-Johnston (1962) [18], tearing fractures such as the epicondyle of the humerus, and fracture of the greater tubercle of the humerus. In combination with metal implants, they were used in any fracture localization where small osteochondral fragments had to be fixed, for example, in fractures of tibial condyles of types II, V, and VI according to J. Schatzker (Fig. 6), fractures of the head of the humerus.

The control group was composed of randomly selected patients with similar fractures who underwent surgery without BDF. There were 132 patients, of whom 65 (49%) were men and 67 (51%) were women. The mean age was 44 (27; 58) years, ranging from 19 to 70 years. The groups did not differ statistically significantly by sex (p=0.902; Fisher's exact test (FET)) and age (p=0.435; U-test). We compared the time spent in the operating room during similar surgical interventions with and without the use of BDFs, the number of operations to remove fixators in both groups, and the number of complications (fixator migration, suppuration, foreign body reactions, secondary displacements); we also compared functional outcomes. We assessed the possibility of interpreting MSCT and MRI data in the isolated use of the BDF.

Statistical analysis was performed using the program «Statistica» 13.3. Data is presented in the form of absolute (n) and relative values (%). Descriptive statistics is presented as median and interquartile range — Me (Q1;

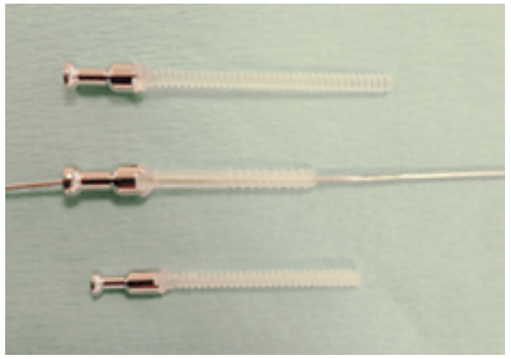


Fig. 1. Biodegradable screws

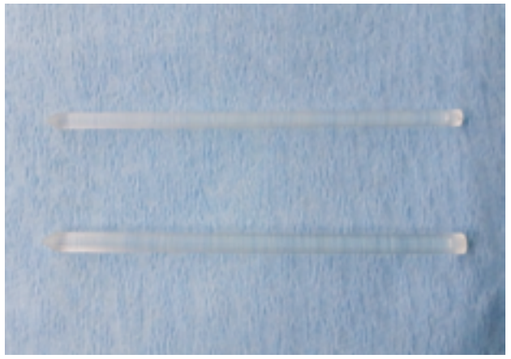
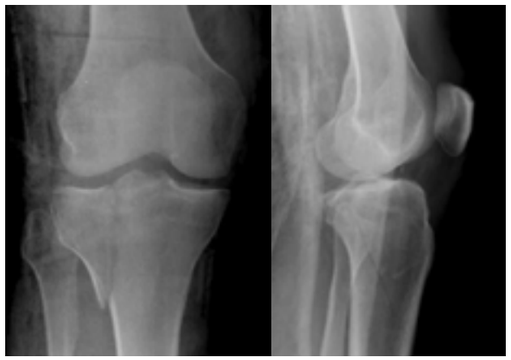


Fig. 2. Biodegradable pins



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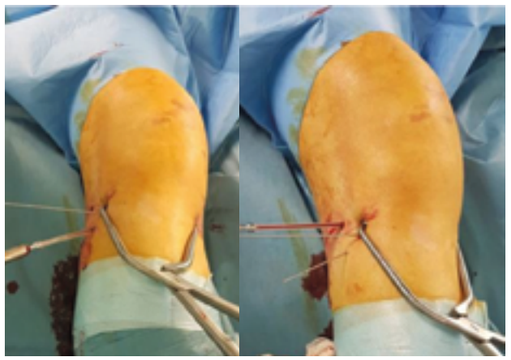

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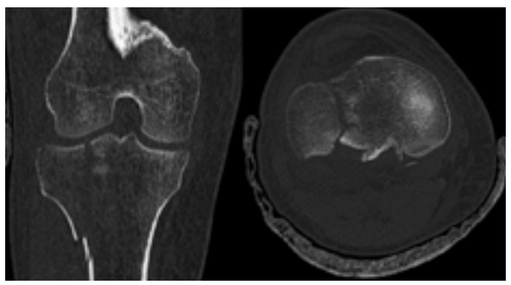

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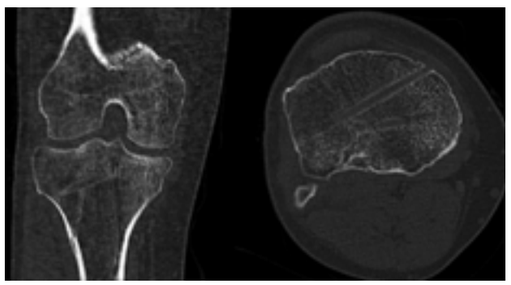

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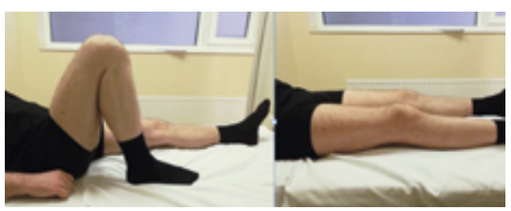

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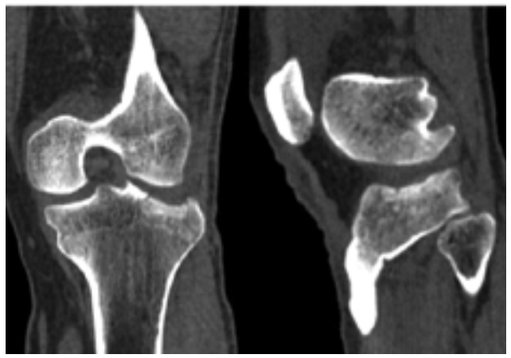
Fig. 3. Type I tibial condyle fracture according to J. Schatzker:
A — preoperative radiographs of the knee joint; B — MSCT of the knee joint;
C — osteosynthesis with cannulated biodegradable screws on spokes;
D — MSCT after 8 weeks. Consolidation of the fragments. Canals from biodegradable fixators are visible, there are no artifacts (glow) as from metal implants; E — function of the knee joint after 6 months



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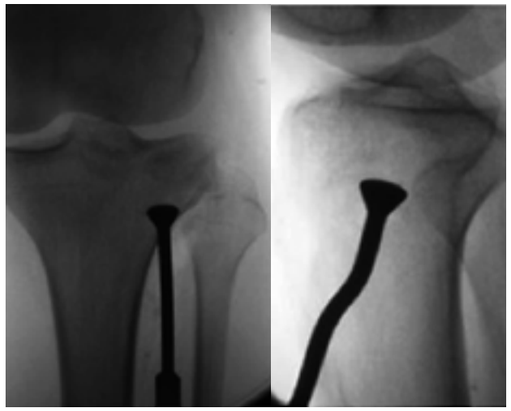

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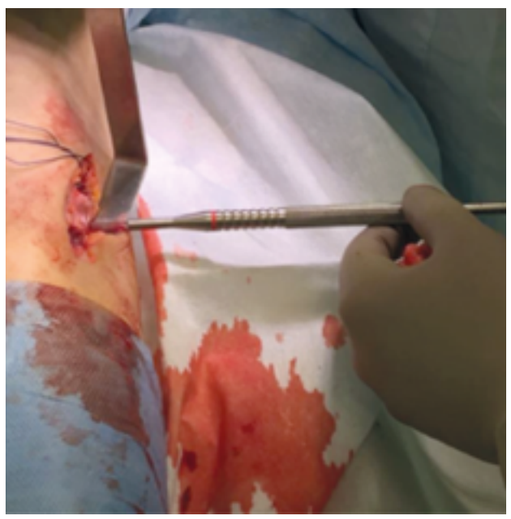

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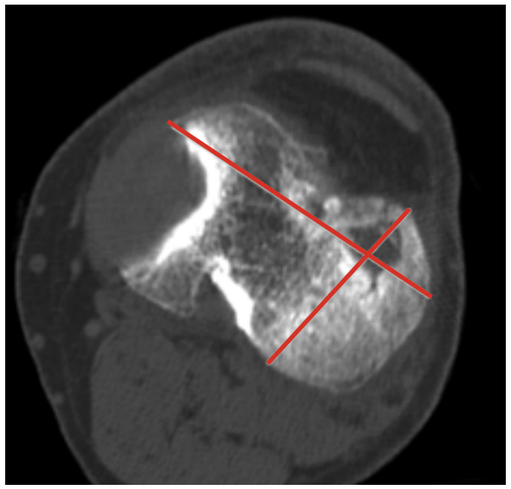

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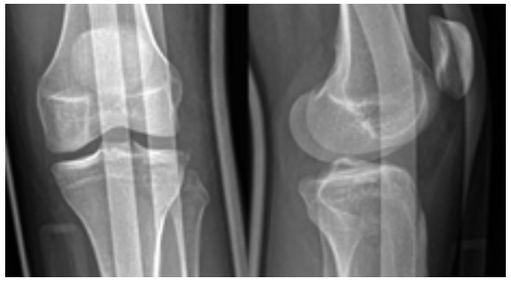

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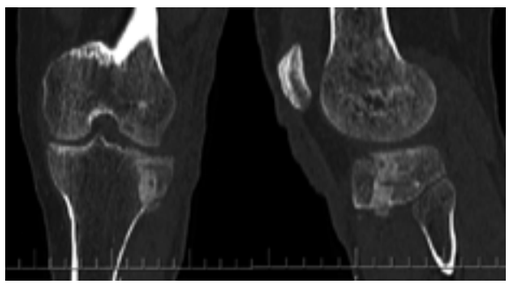

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Fig. 4. Type III fracture of the tibial plateau according to J. Schatzker:
A — preoperative MSCT of the knee joint; B — repositioning of the Impressed tibial plateau; C — insertion of a biodegradable pin after elevation of the Impressed area; D — creation of a support grid from biodegradable fixators;
E — radiographs after surgery; F — CT scan after surgery: channels from biodegradable pins are visible. No interference from implants

Q3), maximum and minimum values. In two unrelated samples continuous data were compared using Mann-Whitney U-criterion (U-cr.), quantitative data — using two-way FET. The level of statistical significance was taken as $p<0.05$.

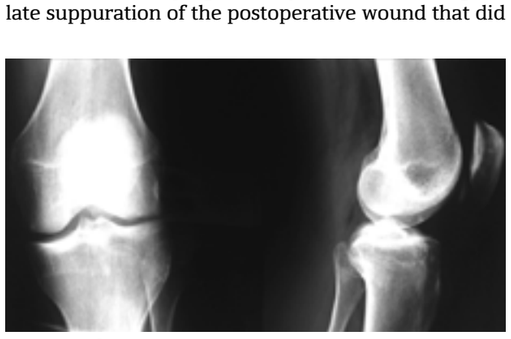
Results. The patients of both groups did not differ statistically significantly by the type of fractures (Table 1).

The time spent in the operating room during surgeries with and without BDF was not statistically significantly different (p=0.871; U-cr.) and was 87 (72; 94), 67 to 102 minutes, and 82 (66; 91), 62 to 94 minutes, respectively.

There were 58 (44%) patients who required removal of metal fixation devices, which was statistically significantly less (p=0.036; TEF) than 76 (58%) patients without BDF. In a comparative analysis of functional outcomes for similar fractures, no differences were found.

Complications developed in 4 (3%) patients observations in the group with BDF use, which was statistically significantly less (p=0.042; TEF) than in the group without BDF use, where the number of complications was 13 (10%).

The following complications were observed in the BDF group: migration of the pin requiring its removal (n=1), impingement syndrome (n=1) (Fig. 7), late suppuration of the postoperative wound that did not require fixation device removal, without outcome of osteomyelitis (n=1), reaction to a foreign body without outcome of osteomyelitis that required fixation device removal (n=1). There were no secondary dislocations of the fragments.



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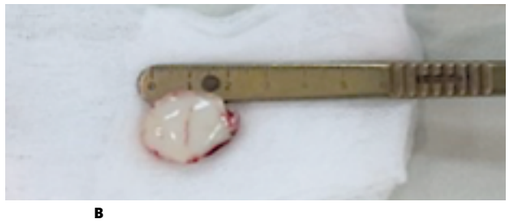

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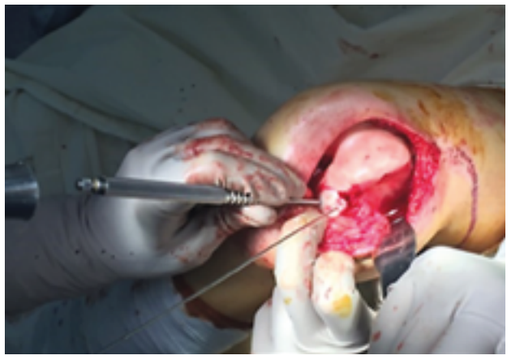

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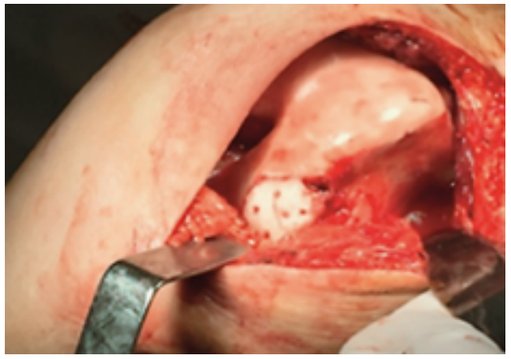

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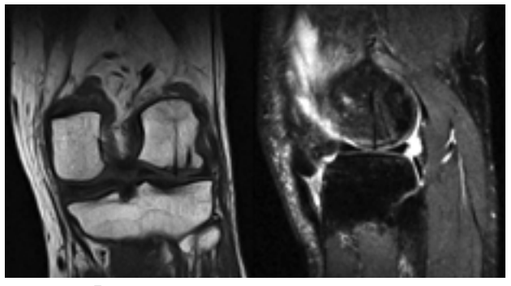

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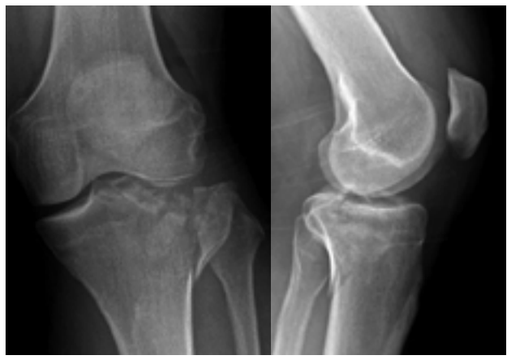
Fig. 5. Bony-cartilaginous fracture of the femoral condyle: A — radiographs of the knee joint: the shadow of the fragment is observed on the lateral projection near the lower pole of the patella; B — bone and cartilage fragment; C, fragment fixation with biodegradable pins; D — fragment fixation with biodegradable pins; E, MRI of the knee joint. No interference from implants

The following complications were observed in the group without BDF use: migration of the spokes (n=4), late suppuration of the postoperative wound (n=2) with an outcome of osteomyelitis, which required removal of fixators (n=1). Secondary fragment displacement (n=6) was statistically significantly more frequent in this group (p=0.029; TEF) than in the BDF group.



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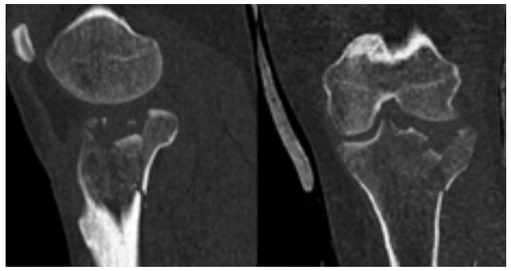

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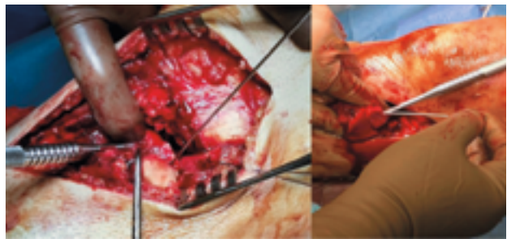

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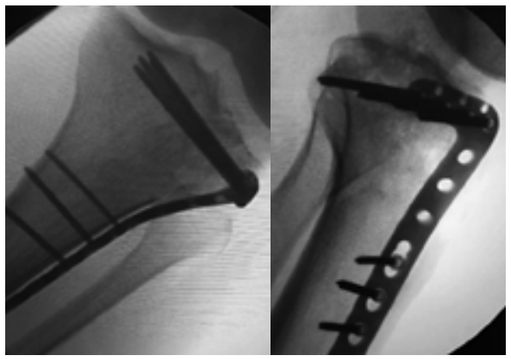

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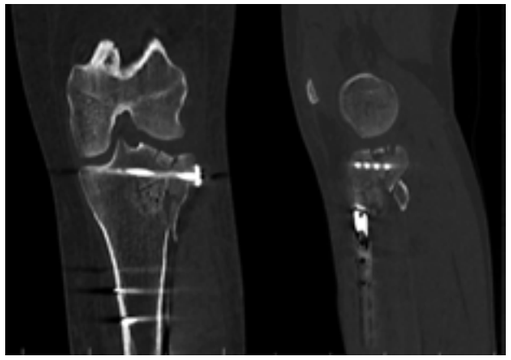

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Fig. 6. Type II fracture of the external condyle of the tibia according to J. Schatzker: A — preoperative radiograph of the knee joint; B — MSCT: fragmented fracture of the external condyle of the tibia; C, fixation of articular fragments with biodegradable pins; D — intraoperative radiography. Example of combined use of biodegradable fixators and metal implants; E — MSCT: articular surface restored

Biodegradable fixators have several differences from metal fixators in use and do not forgive non-compliance with the rules of their installation. They are very durable to tear, but elastic

Biodegradable fixators have several differences from metal fixators in use and do not forgive non-compliance with the rules of their installation. They are very durable to tear, but elastic. By screwing the screw into the bone with force it is not possible to achieve compression, because the screw deforms. There is a certain inconvenience to you about this. Interfractal compression can be created with repositioning forceps, and it will be even stronger after fixation as a result of the self-compression effect. X-ray-negativity of the BDF is inconvenient. However, since the instruments for their insertion are metal, one must be guided by the position of the drill in the bone or the spoke while using cannulated screws.

Only in one case we encountered a complication specific to polymeric fixators — a foreign body rejection reaction. A fistula appeared 2 months after fixation of the tibial bones with a biodegradable screw for an intertibial syndesmosis rupture. The discharge was sterile on culture. Reoperation was required. Intraoperatively, a polymeric mass was formed in the place of the screw, which we removed, and the patient had no problems afterwards.

Impingement syndrome developed due to an error in determining the screw length (Fig. 7). A patient with a type I fracture of the external condyle of the tibia according to J. Schatzker, underwent osteosynthesis with biodegradable screws. After 6 weeks, the patient complained of intermittent pain on the inner surface of the tibia, in the projection of the "goosefoot" attachment. Palpation and then radiological examination revealed excessive protrusion of the biodegradable screw outside the bone, but it had no effect on fracture consolidation (Fig. 7, 8). The patient refused the proposed surgery to correct the length of the screw.

In the control group, secondary displacement of fragments was observed in 6 cases during control radiography 6 weeks after osteosynthesis of tibial plateau fractures. Plateau subsidence within 5 mm was detected. These were type II and type V fractures according to J. Schatzker with fragmentation of the external plateau of the tibia during compression in 5 cases and in one patient, when the subchondral screws of the preformed plate went lower than desired relative to the plateau surface. In the comparison group, subchondral biodigradable pins appeared to prevent this kind of displacement. The installed BDFs did not interfere with MRI, nor did they interfere with the interpretation of postoperative MSCT and MRI data.

Discussion. About 40 years have passed since the first series of osteosynthesis with biodegradable implants in 1984 [19]. During this period, BDFs have proven their utility in surgery. The very idea of biodegradable implants was to prevent repeated operations to remove metal structures after fracture consolidation. Once the fracture has healed, the implant is irrelevant, but sometimes it can present a problem as an individual body reaction, or be a source of pain, discomfort or limited joint motion. In addition, reducing the number of surgical interventions prevents all possible risks of surgical treatment. An important aspect of their use is the financial component. O. Bostman calculated that if the removal rate of metal implants exceeds 19-54% (depending on the type of fracture), biodegradable implants will be cost-effective, since repeated soft tissue trauma is eliminated and the risk of infectious complications is reduced, resulting in lower treatment costs [16, 20].

The first series of osteosynthesis with biodegradable implants were performed for ankle fractures and showed good results [19, 20, 21]. Intertibial syndesmosis fixation was performed with success and good results [22, 23]. The series showed the advantages of biodegradable screws — the percentage of reoperations in case of BDF syndesmosis fixation failure is lower than the percentage of performed removals of metal screws after syndesmosis repair. In our group of patients with syndesmosis damage, only in one

Table 1. Types of fractures by group

Type/localization of the fracture	Patient group				p, FET
	With the use of BDF (n=132		Without BDF (n=132)		
	n	%	n	%	
Fracture of the plateau of the tibia	36	27	31	23	0,572
Patella	2	2	3	2	1,000
Fracture of the distal humerus	34	26	30	23	0,667
Fracture of the radial head	20	15	22	17	0,867
Lesions of the intertibial syndesmosis	20	15	24	18	0,621
Bone-cartilage fractures in the knee joint	1	1	2	2	1,000
Bone-cartilage fractures in the shoulder joint	2	2	4	3	0,684
Tearing fractures	4	3	5	4	1,000
Fracture of the head of the humerus	10	7	8	6	0,810
Fracture of femoral condyles	3	2	3	2	1,000
TOTAL	132	100	132	100	

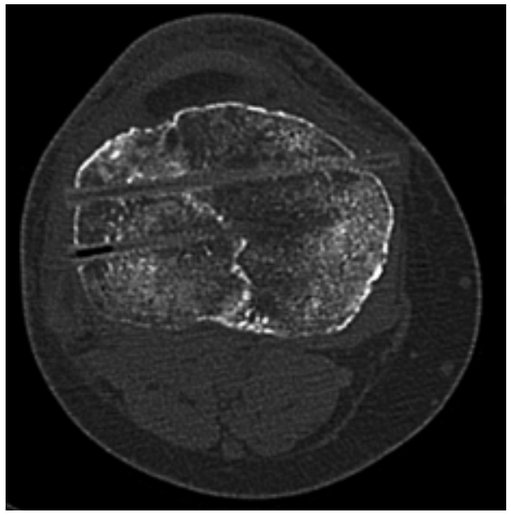

Fig. 7. CT scan of the knee joint. Prominent biodegradable screw

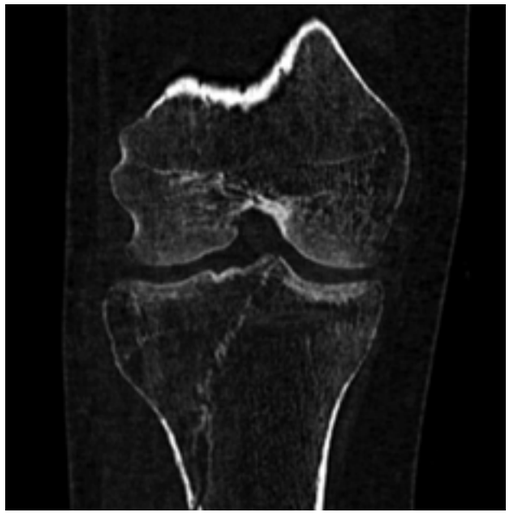

Fig. 8. CT scan after 6 weeks from the date of surgery. Signs of fragment consolidation

An important aspect of their use is the financial component. O. Bostman calculated that if the removal rate of metal implants exceeds 19-54% (depending on the type of fracture), biodegradable implants will be cost-effective, since repeated soft tissue trauma is eliminated and the risk of infectious complications is reduced, resulting in lower treatment costs

case there was a complication (reaction to a foreign body), which required reoperation 3 months later. It did not lead to fixation failure; it required removal of the jelly-like mass from the screw degradation. The functional results were also unaffected.

Excellent osteosynthesis results have been demonstrated for radial head fractures. In several study series, good or excellent radiological and functional results were obtained [24, 25]. In other study, the midterm clinical and functional results were rated as good, although a secondary fragment displacement was observed radiologically in 8.5% of patients, which had no effect on the functional outcome [26]. In our study group, the clinical and functional results are consistent with those presented in the literature.

In our practice, we evaluated the possibility of using biodegradable implants in osteosynthesis of intraarticular fractures, namely, fractures of the tibial plateau of types I and III according to J. Schatzker, when conventionally used metal screws were replaced with biodegradable ones, which allowed us to avoid repeated surgical intervention for implant removal. In our comparison group, none of the patients required removal. One patient had a complication in the form of impingement syndrome due to incorrect calculation of the biodegradable screw length, which led to irritation of the ligament apparatus of the knee joint on the inner surface of the tibia. The patient refused to have the screw length corrected. The use of BDF for plateau fractures was mentioned once in the literature [27]. In this series, synovitis in the knee joint developed among other

complications, and the author regarded this as a reaction to the polyglycolide (PGA) BDF, as well as secondary displacement of the fragments, which required a second surgery with metal implants.

The undeniable advantage of biodegradable pins is the ability to fix small osteochondral fragments to each other when the articular surface is fragmented. The area where biodegradable pins are placed is the subchondral bone, the area from which implants cannot be removed in the future. And in this case, BDFs are the best suited for osteosynthesis. No examples of the use of BDFs in such cases have been found in the literature.

Conclusion. Biodegradable fixators have a wide range of applications; they have proven themselves both in isolation for intraarticular and tear fractures and in combination with metal implants. With biodegradable pins it is reasonable to carry out transchondral fixation of small fragments, to merge small articular fragments into large ones for complete restoration of the fragmented joint in combination with metal structures. It is reasonable to carry out fixation of osteochondral or bone fragments with screws, passing them through a metal plate or without it. The use of BDF did not increase the time of surgical intervention. Removal of fixators was statistically significantly less frequent when BDF was used. Local complications in the postoperative period, including secondary displacement of the fragments, developed statistically significantly less frequently when BDF was used than during surgical treatment without BDF. The presence of BDFs, even before their complete biodegradation, did not prevent the performance and interpretation of MRI of the operated joint.

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Results of autologous peripheral hematopoietic stem cell transplantation in multiple myeloma in Kyrgyzstan

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Abstract. The article is devoted to performing a series of autologous transplantations of peripheral hematopoietic stem cells in multiple myeloma (MM). For the first time in Central Asia, in the Kyrgyz Scientific Center of Hematology of the Ministry of Health of the Kyrgyz Republic, autologous hematopoietic stem cells were used in the treatment of 26 patients with MM. Comprehensive laboratory and functional analyses were carried out to diagnose MM. Autologous stem cells were collected using the blood cell separator. Conditioning mode and an algorithm of therapeutic approaches of patients before autotransplantation and post-transplantation monitoring were used.

Keywords: autologous transplantation of hematopoietic stem cells, multiple myeloma, melphalan-autologous, blood cell separator, conditioning, monitoring.

Abstract. For the first time in Central Asia, in particular, in the Kyrgyz Scientific Center of Hematology of the Ministry of Health of the Kyrgyz Republic, autologous hematopoietic stem cells were used in the treatment of 26 patients with MM. Comprehensive laboratory and functional studies for the diagnosis of MM were carried out, autologous stem cells were collected on a blood cell separator. A conditioning regimen was used, a differentiated approach to the treatment of patients before autotransplantation and post-transplant monitoring was applied.

Introduction. Each year in Kyrgyzstan there are registered more than 60 patients with multiple myeloma (MM). In the first six months of 2015, more than 200 patients with leukemia, including 30 patients with myeloma, were registered at the consultative and diagnostic department of the Kyrgyz Scientific Center of Hematology of the Ministry of Health of the Kyrgyz Republic (KSCH MH KR).

Until 2005, we treated MM patients mainly using melphalan-prednisone (MP) and vincristine-doxorubicin-dexamethasone (VAD) programs, whereas more modern chemotherapy drugs, such as bortezomib (Velcade), lenalidomide, thalidomide are not registered with the Department of Medicine Provision and Medical Equipment under the Ministry of Health of the Kyrgyz Republic (DMP ME MH KR), and it is not profitable for pharmaceutical companies to supply them due to low demand. However, over the past 3 years, we have started to widely apply a treatment program with bortezamib and lenalidomide, which patients' relatives purchase outside our republic (Figure 1).

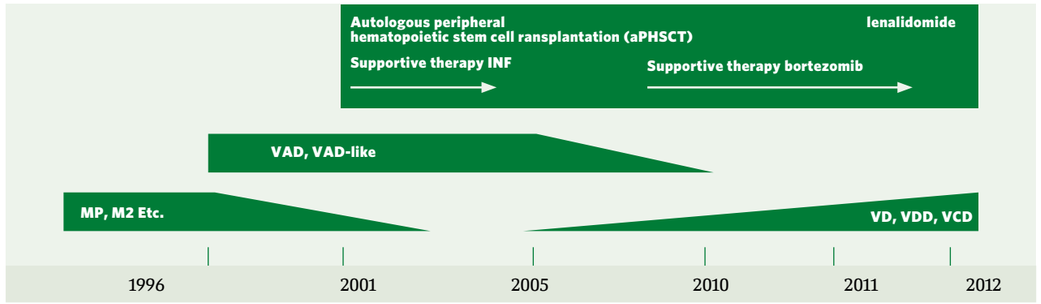


Fig. 1. The evolution of multiple myeloma treatment in the Kyrgyz Scientific Center of Hematology of the Ministry of Health of the Kyrgyz Republic

It is known that high-dose chemotherapy (HDC) followed by autologous peripheral hematopoietic stem cell transplantation (auto-HSCT) has proven to be one of the most effective treatment methods [9, 10].

In our small country with a relatively unstable economy and low income level of the population, drug treatment of patients with leukemia, as well as Autologous peripheral hematopoietic stem cell transplantation (aPHSCT) is a major problem, the solution of which is aimed at the scientific and clinical potential of KSCH MH KR.

Autologous transplantation of peripheral hematopoietic stem cells for the first time in Central Asia was introduced at KSCH MH KR in 2007 according to the project written by Professor A.R. Raimzhanov and supported by scientists-hematologists of Turkey headed by Professor Suleiman Dincher and Turkish International Cooperation Organization (TIKA) under the Prime Minister of Turkey.

According to the agreement concluded between KSCH MH KR and TIKA, a joint Kyrgyz-Turkish bone marrow transplant center was established on the base of KSCH MH, 7 doctors and 2 nurses underwent a 3-month training in the bone marrow transplant centers in Turkey.

Despite the fact that new drugs (bortezomib, lenalidomide) are being introduced into clinical practice for the treatment of MM, their combination with aPHSCT is considered the standard therapy for patients with MM.

In its annual reports, the European Society for Blood and Marrow Transplantation (EBMT) indicates a steady increase in the number of aPHSCTs. Accordingly, in 2016, 22,806 aPHSCTs were performed in Europe [13].

Clinical case. Patient O., 48 years old, who underwent aPHSCT surgery for the first time in Kyrgyzstan.

In September 2005 the patient was diagnosed with multiple myeloma, diffuse focal form with hyperproduction of monoclonal IgG. General blood test dated September 30, 2005: er. — 4.9×10^{12}/l, Hb — 121 g/l,

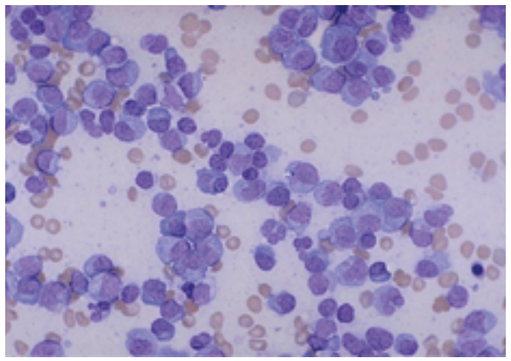


Fig. 2. Tumor substrate

High-dose chemotherapy followed by autologous transplantation of peripheral hematopoietic stem cells has proven to be one of the most effective methods of treatment for multiple myeloma

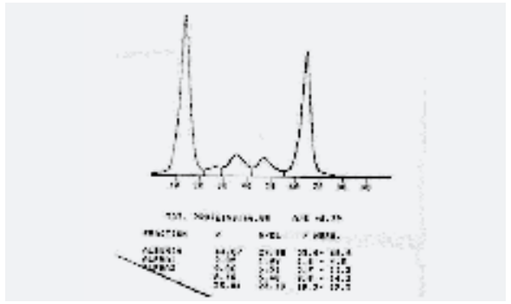


Fig. 3. M-protein on the electrophoregram of serum proteins

hematocrit — 41.7%, plt. — 369.3×109/l, leuk. — 9.8×109/l, lymph. — 25%, band. — 2%, segm. — 71%, mon. — 2%, erythrocyte sedimentation rate (ESR) — 62 mm/h.

In the bone marrow the number of plasma cells was 25%, IgG level was 32.5 mg/ml (Fig. 2).

Prolonged MP therapy was prescribed (melphalan 10 mg/day, a course dose of 200 mg, and prednisolone 60 mg for 10 days, with subsequent reduction). Then, maintenance therapy under the MP shock intermittent therapy scheme of (melphalan 14 mg for 4 days, prednisolone 60 mg for 4 days, with intervals of 6 weeks) was administered.

The treatment resulted in complete clinical and hematological remission. For a year and a half, the patient was under the follow-up of hematologists of the KSCH MH KR, all necessary laboratory and instrumental examinations were regularly carried out.

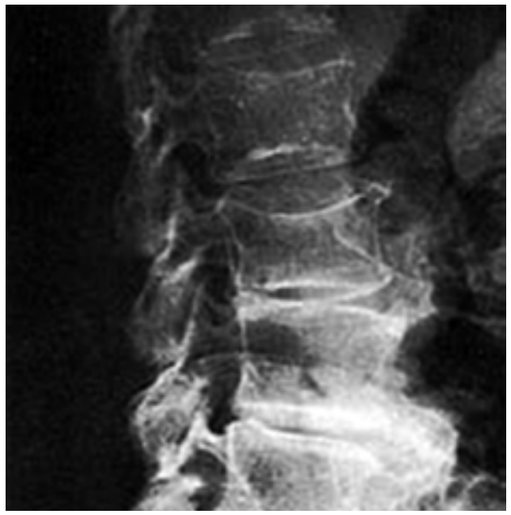
High-dose melphalan chemotherapy (140-200 mg/m2) with aPHSCT is the benchmark for remission consolidation and the therapy of choice for patients younger than 70 years of age. The rate of complete remission after melphalan induction therapy reaches 34.1% of patients, whereas after aPHSCT the rate of complete remission reaches 61% [5]. Hundred-day survival rate is 100%, median overall survival exceeded 38 months.

Our data correlates with the results of treatment of 75 patients with MM using melphalan conditioning regimen at a dose of 140-200 mg/m2 according to the program (melphalan autologous) [5].

The patient was hospitalized in the Department of Hematology of the KSCH MH KR to consider the issue on autologous bone marrow transplantation on March 29, 2007.

All laboratory and functional examinations of the patient were carried out in the department of laboratory diagnostics of KSCH MH KR using a hematological analyzer "Diatron" (Austria), a biochemical analyzer "Humalaizer" (Germany), a protein fraction analyzer "Scanion" (Austria), an immunoenzymatic analyzer "Sun-Rise" (Austria), microscopes "Zeiss" (Germany), "Olimpus" (Japan).

- General blood test dated March 30, 2007: er. — 5.25×1012/l, Hb — 148 g/l, hematocrit — 45%, MCV — 85.7 fl, MCN — 28.2 pg, MCHC — 33.0 g/dl, tr. — 252.0×109/l, leuc. — 6.2×109/l, lymph. — 1.4×109/l (22%), gr. — 4.5×109/l (73%), mon. — 0.3×109/l (5%), ESR — 30 mm/h.
- Biochemical tests dated March 30, 2007: total bilirubin — 4.3 mm/l, thymol test — 4.4 units, ALT — 4.1 units/l, AST — 4.0 units/l, urea — 2.2 mm/l, creatinine — 79 μm/l, serum iron — 14.8 μm/l, blood sugar — 5.27 μmol/l, cholesterol — 4.07 μmol/l, amylase —210 units/l.
- Electrophoresis of blood serum proteins: total protein — 66 g/l. Albumin — 44.07%: α1-globulins — 2.85%, α2-globulins — 9.06%, αglobulins — 8.16%, αglobulins — 35.84%, coefficient A/G=0.91 (Fig. 3).
- Immunoglobulins from 02.04.2007: IgA — 4.0 mg/ml; IgM — 2.0 mg/ml; IgG — 17.8 mg/ml.
- CMV IgG — 1:400.Herpes (1+11) — 1:200. Toxoplasma IgG — 1 unit/l. Syphilis (RW) — Nil.
- T3 — 1.67 nmol/l, T4 — 115 nmol/l, TSH — 0.685 mmol/l, anti-TPO antibodies — 10.0 ME/l.
- Viral hepatitis markers: HBV: HbsAg — negative, Anti HBC IgM — negative; HCV: Anti HDV IgG — negative; HCV: Anti HCV IgG — negative.
- Urinalysis dated March 03 2007: color — malt-yellow, reaction — acidic, urine specific gravity — 1028, total transparency, protein — 0.03, ep. cells — units per field of view, leuk. — 2-3-2 per field of view
- Myelogram dated March 30, 2007. Conclusion: sternal punctate is abundantly cellular. Granulocytic sprout — 48,6%. Erythroid sprout — 34,6%. There were megaloblasts on the background of the normoblastic type of hematopoiesis. There were no changes in the lymphoid sprout (11.1%). Plasma cells — 2.9%. Megakaryocytes are normal.
- Hemostasiogram: platelets — 615.0×109/l, platelet adhesion — 61%, platelet aggregation — 8 s, autocoagulogram at 8 min. — 21 s, at 10 min. — 16 s, kaolin time — 72 s, INR — 1.23; prothrombin time — 22 s — 82%, fibrinogen "A" — 4888 mg/L, fibrinogen "B" +, ethanol test — weakly +, protamine time — neg., thrombin time — 23 s, thrombotest — 1V, euglobulin fibrinolysis — 190, spontaneous fibrinolysis — 20%, blood clot retraction — 63%, clot volume — 53%, ratio of solid to liquid phases — 1.3; hematocrit volume — 37%, PTT — 39 s, FMC — 13.0 mg.
- Radiography of the thoracic and lumbosacral spine and pelvic bones. Conclusion: wedge-shaped deformation of the Th12 bodies, rounded defects of the cranial vault (Fig. 4).



A

B

Fig. 4. X-ray of the thoracic and lumbar spine and skull dated September 26, 2005: wedge-shaped deformity of Th12 bodies, rounded defects in the skull vault area

- Ultrasound examination dated March 30, 2007: echo-signs of chronic cholecystitis, microlithiasis of kidneys.
- ECG dated March 30, 2007: sinus rhythm. Heart rate 62 per min. Normal position of the electrical axis of the heart.
- EchoCG dated March 30, 2007: no areas of hypokinesis.
- PFT dated March 30, 2007: parameters of VC and airway conductance were within normal range.
- Consultation and prophylactic treatment by a gynecologist.
- Sanation of the oral cavity by a dentist (dental caries).
- It is known that almost 80% of patients in the onset of MM, as in our patient, have typical radiological bone lesions [8].

The first operation of aPHSCT for a patient with MM (KSCH MH KR, Bishkek, May 15, 2007) was performed by Professor Suleiman Dincher with the staff of KSCH MH KR.

Stem cells were collected using a blood cell separator. These stem cells were then placed in a laminar flow cabinet into hemofreeze bags, which were placed in containers in a tank of liquid nitrogen (-196°C).

Treatment administered:

- Bactrim 960 mg × 2 times a day #32.
- Allopurinol 100 mg by 2 tablets × 3 times a day #42.
- Nystatin 500,000 units. 4 times a day #72.
- Diflucan 200 mg × once a day #20.
- Valtrex 500 mg × 1 time per day #18.
- Nolycin 400 mg 1 tablet 2 times a day.
- Holudexan 300 mg 1 capsule at night per orally.
- Omeprazole 20 mg 1 capsule per orally.
- Melphalan 50 mg 100 mg per 100 ml of saline intravenously by drip #2.
- Kitril 3 mg 3 ml intravenously per 50 ml of saline #3.
- Autologous stem cells 50 ml intravenously by drip #5.
- Neupogen 30 million units p/k 2 times a day #16.
- Saline solution 500 ml by intravenous drip 1.5-2 liters per day.
- Donor thromboconcentrate 16 doses #2 intravenously.
- Potassium chloride 10.0 ml per 400 ml of saline solution intravenously by drip.
- Glucose 5% —500 ml intravenously by drip.

Algorithm of treatment approaches for aPHSCT candidates: all patients with newly diagnosed MM under the age of 70, in the absence of contraindications (severe infections, cardiac, pulmonary insufficiency, marked liver dysfunction); renal failure is not an absolute contraindication. Each case requires an individual approach [3].

Induction chemotherapy: VAD, preferably 3-component programs (bortezomib + dexamethasone + doxorubicin or cyclophosphamide) — 2-4 courses.

From May 2007 to May 2016, 26 peripheral hematopoietic stem cell transplantations (PHSCTs) were

performed in KSCH MH KR to 26 patients with MM (19 men and 7 women aged from 48 to 63 years, mean age 54 years) (Figure 5). All of them were treated mainly with the VAD regimen, and in 2014-2016 they were treated with — bortezomib [5, 7, 15, 16, 17]. Two patients at the first recurrence were re-treated with auto-HSCT when the second remission was reached, and 2 more patients with an aggressive form of MM underwent aPHSCT without achieving complete remission after 4 courses of VAD. The international group of experts indicates relatively deep anti-tumor response and survival rate when applying aPHSCT in MM patients younger than 70 years old [11, 14].

The number of CD34+ cells in the transplant is one of the factors affecting the recovery time of hematopoiesis in the post-transplant period [19].

PHSCs mobilization — stimulation of GM-CSF 10 μg/kg per day, 6 days, 1-2 apheresis. Target CD34+ collection of more than 2×106/kg patient weight.

After a 2-3-week interval: aPHSCT — conditioning with melphalan 140-200 mg/m2, infusion of PHSC more than 2×106/kg every other day [1].

The median number of transfused CD34+ corresponds to the data obtained by Kostroma I.I. et al. in 2019 [2].

None of the 26 patients who received high-dose chemotherapy with PHSCT from 2007 to 2016 received maintenance therapy. Although bortezomib maintenance therapy after autologous aPHSCT in MM is mandatory to reduce recurrence and the risk of progression or death by 50% [6, 12, 18].

Progression (recurrence) was registered in 9 patients with MM.

Stable condition was preserved in 17 patients, who continued monitoring.

Post-transplant monitoring:

- quantification of serum immunoglobulins and immunoelectrophoresis/immunofixation after 1, 3, 6, 9, 12, 18, 24, 30, 36 and 48 months;
- quantitative determination of Bence-Jones protein and free light chains in serum and urine at the same time points;
- bone marrow aspiration biopsy at 3, 6, 12, and 24 months or when paraprotein levels are elevated;
- bone condition assessment: R-Graphy/MRI (if there were bone changes before aPHSCT or for clinical indications) after 6, 12, 24 and 36 months;
- response assessment: immunochemical testing of blood and urine, morphological study of bone marrow (evaluation of the remaining pathological clone of plasmacytes).

aPHSCT without achieving complete remission: two MM patients with an aggressive course did not achieve complete remission after 4 courses of VAD. It has been proven that aPHSCT is best to be performed as soon as the first remission is achieved [4].

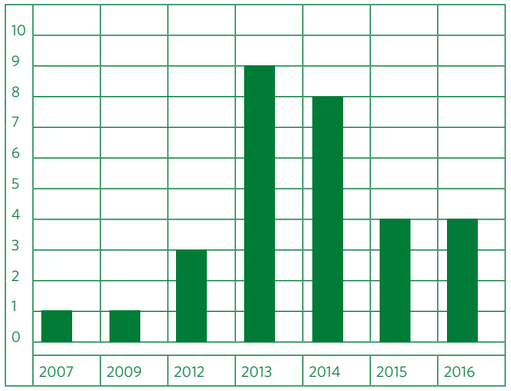


Fig. 5. Peripheral hematopoietic stem cell transplantations for multiple myeloma in the KSCH MH KR from May 2007 to August 2016

After performing the aPHSCT program, a complete remission was obtained, which lasts up to 38 months.

The follow-up will be continued.

Results of repeated aPHSCT in MM progression (n=2): 100-day survival rate — 100%.

Recurrence-free survival rate after repeated aPHSCT is more than 36 months.

Unfortunately, autotransplantation of autologous peripheral hematopoietic stem cells is consistently accompanied by incoming immunosuppression, compensation of which is well described in the world literature [20].

Conclusion. Remission from the first or two standard courses of chemotherapy before aPHSCT has a favorable prognostic value.

Our data confirms the fact of improved survival in MM patients with an aggressive form when they undergo aPHSCT, without achieving complete remission from standard courses (insufficient data).

Post-transplant monitoring to detect progression and timely performance of repeated aPHSCT probably allow to obtain similar results.

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Endoscopic treatment of degenerative spinal canal stenosis

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Abstract. Microsurgical decompression technique has been regarded as the standard surgical method in degenerative spinal diseases to date. The conventional method may lead to instability and lead to chronic lower back pain due to injury of facet joints, posterior ligamentous complex, as well as paraspinal muscles. To avoid these complications, the new biportal endoscopic technique has been introduced in our clinical practice. Since 2019, we have been widely using this technique and for the first time in Russia we have accumulated unique experience that allowed us to complete this article.

The aim of this study is to demonstrate a new biportal endoscopic spinal surgical technique's possibility in treatment of degenerative lumbar spine diseases and to report the results of using this technique in our clinic.

Study design: retrospective study.

One hundred two patients who were suffering from neurologic symptoms by degenerative lumbar spine diseases were included in study. All patients were divided into 3 groups according to the clinical condition: 1st group — patients with degenerative central spinal stenosis who underwent biportal endoscopic bilateral decompression using a unilateral approach, 2nd group — patients with foraminal spinal stenosis who underwent biportal endoscopic foraminotomy using a extraforaminal approach, 3rd group — patients with degenerative monosegmental instability, degenerative or isthmic spondylolisthesis who underwent biportal endoscopic lumbar interbody fusion. Clinical outcomes were analyzed in accordance with modified-Macnab criteria, Oswestry Disability Index (ODI), Numeral rating scale (NRS), also postoperative complications were analyzed.

There was a significant improvement in the dynamics of pain syndrome, ODI scale in all 3 groups. According to the McNab scale, no unsatisfactory results were observed in any group. There were 4 cases of durotomy. In all cases, the durotomy did not exceed 3 mm and did not require further treatment. No cases of infectious complications were identified.

Biportal endoscopic surgery can be considered an alternative to the traditional microsurgical technique of spinal decompression and spinal fusion in the lumbar spine. The use of this technique can significantly reduce muscle trauma, achieve sufficient decompression, and reduce the frequency of infectious complications.

Keywords: biportal, endoscopic, stenosis, lumbar.

Table 1. General characteristics of patients in the groups.

Category	Indicators	Groups		
		1st	2nd	3nd
Socio-demographic aspects	total number of participants	57	24	21
	age (median)	64	62	57
	gender (male)	23	10	13
Concomitant pathology	L2–L3	4	1	0
	L3–L4	12	2	2
	L4–L5	38	6	11
	L5–S1	3	15	9

Introduction. Degenerative stenosis of the lumbosacral spine is the most common indication for surgical treatment in spinal surgery. This disease has an extremely high social and economic significance, since it leads to constant pain and loss of ability to work [1, 2]. Low efficiency of conservative and disadvantages of traditional surgical treatment prompt specialists worldwide to search for ways to improve surgical approaches in order to minimize tissue trauma, reduce the probability of postoperative instability development, and accelerate the recovery process in the postoperative period [3, 4]. Thus, open surgery for degenerative stenosis was replaced by microsurgical techniques with the use of various wound spreaders. The introduction of microsurgical minimally invasive technique of bilateral decompression from unilateral access significantly improved postoperative outcomes, but the issue of postoperative chronic back pain and epidural fibrosis was not completely solved [5-7].

Further development of minimally invasive technologies led to the introduction of percutaneous fully endoscopic single-port decompression of the spinal canal into the practice since the early 2000s [8, 9]. however, the necessity for expensive equipment and special instruments, as well as the need for sufficient experience limit the widespread use of the technique [12].

In 2016, the first publications appeared dedicated to the clinical use of a new method of minimally invasive spine surgery — biportal fully endoscopic technology [13, 14]. The technique is based on the principle similar to arthroscopic surgery, which is the use of two ports, where one port is for the endoscope, and the second one is for working instruments. Surgical endoscopic anatomy is similar to microsurgical anatomy, allowing physicians to better navigate the operating field. Additionally, the use of standard instruments significantly reduces the cost of surgeries.

Since 2016, a number of articles on this technique have been published, several articles on a comparative analysis of biportal endoscopic and microsurgical decompression for spinal canal stenosis in the lumbar spine.

It is worth noting that no articles on this topic published in Russia have been found. Some studies have shown that the biportal endoscopic technique has a number of advantages over the microsurgical technique in terms of pain severity and dynamics, length of hospital stay, etc. [15-19].

We have been widely applying this technique since 2019, and for the first time in Russia we have accumulated unique experience that has allowed us to write this article.

Purpose. The study objective was to demonstrate the potential of a new biportal endoscopic surgery technique for the treatment of patients with degenerative stenosis of the spinal canal in the lumbosacral spine and to report the first results of using this technique.

Materials and methods. The study included 102 patients with degenerative spinal canal stenosis, degenerative monosegmental instability, and degenerative or isthmic spondylolisthesis in the lumbosacral spine who were operated on using biportal endoscopic technology at I.P. Pavlov PSPbGMU between August 1, 2019 and January 1, 2021. The baseline characteristics are presented in Table 1.

The diagnosis was based on clinical data: findings of radiological and instrumental investigation methods.

Group 1 included patients with degenerative central stenosis of the spinal canal in the lumbosacral spine (C-D grade according to C. Schizas classification), who were operated on using biportal endoscopic bilateral decompression via unilateral access.

Exclusion criteria:

- previous surgical treatment in the operated segment;
- spondylolisthesis in the operated segment;
- signs of instability in the operated segment based on functional spondylograms
- degenerative scoliosis.

Group 2 included patients with single-level degenerative foraminal stenosis of the spinal canal in the lumbosacral spine (types 2 and 3 according to S. Lee classification), who were operated on using biportal endoscopic foraminotomy with extraforaminal access.

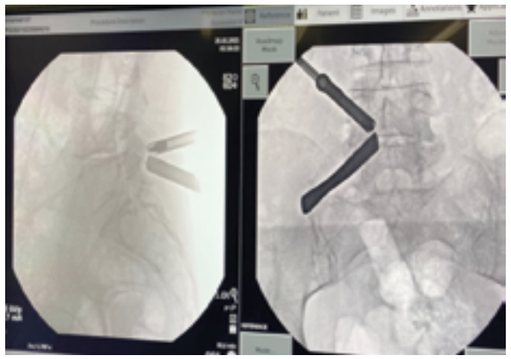


Fig. 1. General view of the location of ports according to the principle of triangulation

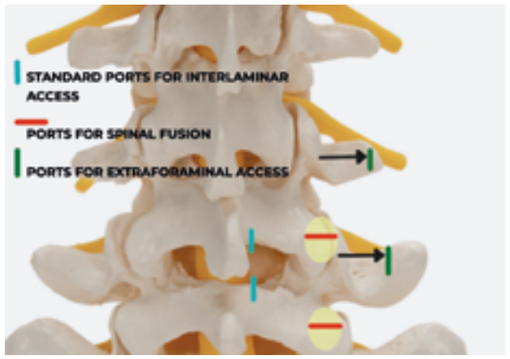


Fig. 2. Demonstration of port formation and maintenance through irrigation

Exclusion criteria:

- previous surgical treatment in the operated segment for foraminal stenosis;
- spondylolisthesis in the operated segment;
- signs of instability in the operated segment based on functional spondylograms
- degenerative scoliosis.

Group 3 included patients with degenerative monosegmental instability, degenerative or isthmic spondylolisthesis in the lumbosacral spine who underwent biportal endoscopic interbody fusion and percutaneous transpedicular fixation surgery.

Exclusion criteria:

- previous surgical treatment in the operated segment;
- gade 3-4 spondylolisthesis in the operated segment.

Treatment outcomes were assessed according to the following indicators: duration of surgery, development of perioperative complications:

- durotomy;
- epidural hematoma formation;

Fig. 3. Location for different biportal endoscopic surgery options

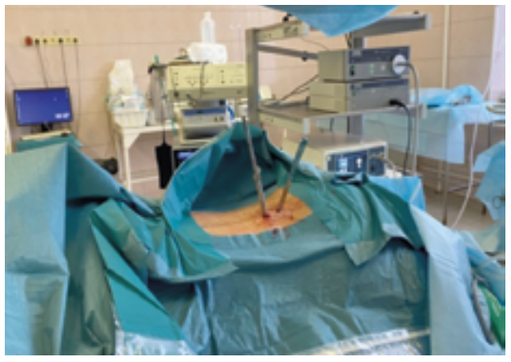


Fig. 4. Port formation with dilators

- liquorrhea;
- damage of neural structures;
- surgical-site infection;
- dynamics of dural sac cross-sectional area (DSA) at the level of stenosis;
- level and dynamics of pain syndrome in the lower back and legs, NRS
- the level of household and social adaptation patients, ODI;
- level of patients' satisfaction with treatment according to the modified Macnab scale.

The surgical interventions were performed with a 4 mm 30° arthroscope (Smith&Nephew), Arthrocare Quantum 2, arthroscopic shaver (Smith&Nephew), and standard spinal instrumentation.

Surgical technique. The basic concept of biportal endoscopic spine surgery. Biportal endoscopic spine surgery is a symbiosis of microsurgery and endoscopy. The basic principle of this technique is the triangulation principle, with the instrument and the endoscope forming a triangle (Fig. 1).

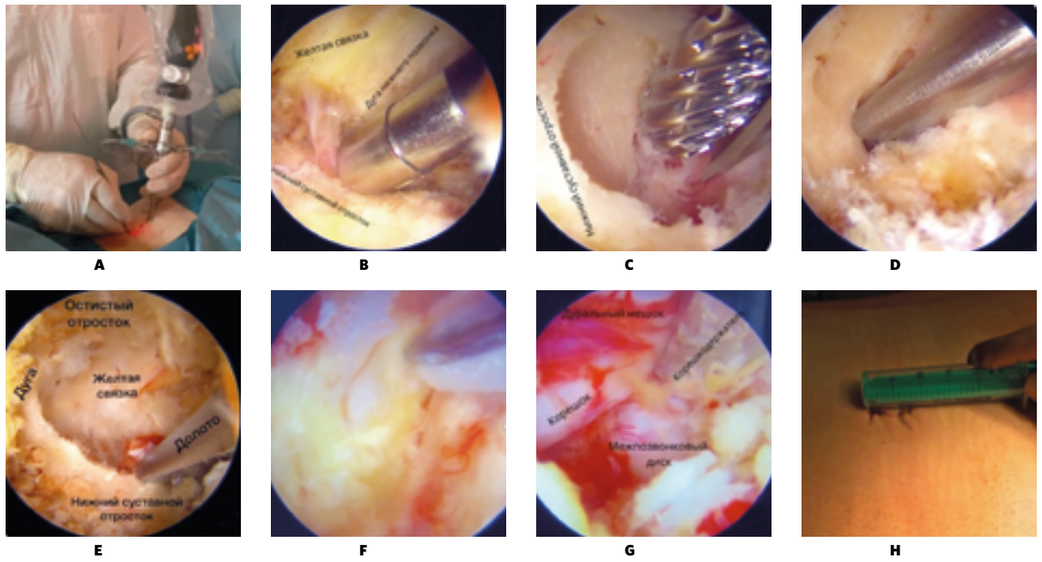


Fig. 5. Biportal endoscopic bilateral decompression using unilateral access: A — port formation stage; B — view of the operating field; C, D, E — stages of bone resection using shaver, Kerrison cutters, chisel; F — wax hemostasis; G — final stage: neural structures and intervertebral disc are visualized; H — postoperative wounds

The working space is formed and maintained by constant irrigation with physiological solution. The working port is also maintained by constant irrigation, which eliminates the need for special tubes (Fig. 2).

Due to the unrestricted working port, it is possible to use almost the entire range of general spinal instrumentation and hemostasis techniques, including several instruments simultaneously.

The success of biportal endoscopic surgery critically depends on optimal port arrangement (Fig. 3).

According to the available literature data, the trajectory of port formation for interlaminar biportal endoscopic surgery is determined on a neutral X-ray image in the direct projection, where the middle of the upper port crosses the lower edge of the superior vertebral arch and the middle of the lower port crosses the upper edge of the superior vertebral arch. However, in the process of mastering this technique, we noted that the optimal angle between the working instrument and the endoscope is 20-22°. This angulation allows to avoid conflict between the working instrument and the endoscope and provides the best viewing angle. Considering these findings, the method of determining the trajectory of the ports and determining the optimal distance between them to achieve the optimal angle between the endoscope and the working instrument has been improved. When performing transforaminal decompression, the key point is the inferior edge of the transverse process of the upper vertebra.

For biportal endoscopic fusion, the working ports coincide with the screw points.

When performing biportal endoscopic fusion, the working ports match the screw points.

In the original technique, the formation of the ports and the working field is carried out using a raspator. Skeletonization of intercostal space is performed using a raspator via both ports.

In the original technique, the formation of the ports and the working field is carried out using a raspator. Skeletonization of intercostal space is performed using a raspator via both ports. In order to reduce muscle traumatization, we improved the method of port and working field formation using a series of dilatators and a working tube (Fig. 4).

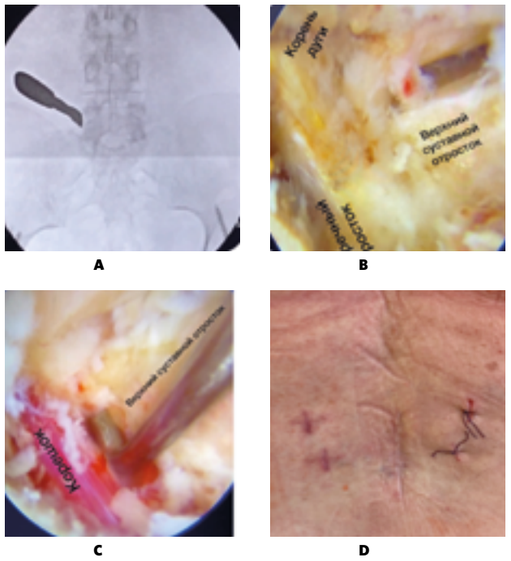
All further manipulations and surgical anatomy do not differ significantly from the conventional microsurgical concept (Fig. 5).

Biportal endoscopic bilateral decompression using a unilateral access. After the formation of working ports, the medial facetectomy, interlaminectomy, removal of the superficial layer of the yellow ligament on the unilateral side are performed, and the next step is resection of the base of the spinous process of the upper vertebra to gain a free access to the contralateral side. The yellow ligament is detached from the inner surface of the arch and lower articular process. A medial facetectomy is performed on

the contralateral side using a shaver or chisel, and the last step is resection of the yellow ligament. Almost all steps are shown in Fig. 5.

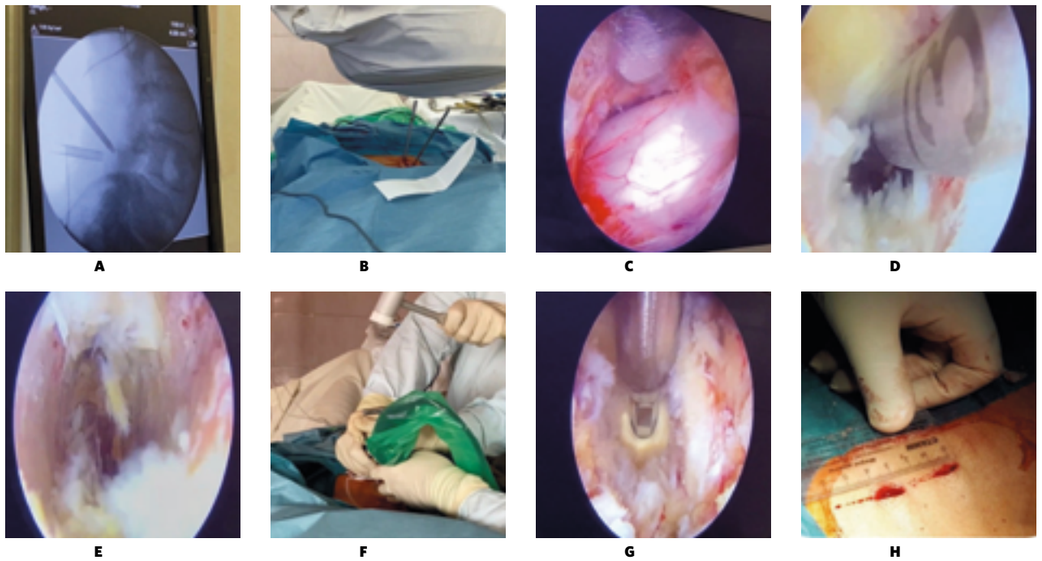
Biportal endoscopic foraminotomy with an extraforaminal access. Ports are formed at approximately 2 cm from the lateral edge of the arch root of the upper and lower vertebrae. An important reference point at this stage is the lower border of the transverse process of the upper vertebra (Fig. 6). The lower edge of the transverse process of the upper vertebra is resected using Kerrison cutters, and the nerve root is visualized. The next step is resection of the upper edge of the upper articular process of the underlying vertebra using a shaver or chisel. If the vertical size of the intervertebral foramen is insufficient then resection of the foraminal part of the intervertebral disc, osteophytes, and resection of the lower wall of the arch root were performed of necessity.

Biportal endoscopic interbody fusion and percutaneous transpedicular fixation. After X-ray marking, port formation is performed in the projection of the lateral edge of the arch roots. Further decompression steps are identical to biportal endoscopic bilateral decompression using unilateral access, except for facetectomy on the ipsilateral side. The decompression step is followed by discectomy, treatment of adjacent vertebral laminae, and placement of the cage (Fig. 7).



A B C D

Fig. 6. Biportal endoscopic foraminotomy with extraforaminal access: A — stage of port formation, the key point is defined; B — view of the operating field; C — final stage: nerve root visualized, D — postoperative wounds after bilateral biportal endoscopic foraminotomy



A B C D E F G H

Fig. 7. Biportal endoscopic interbody fusion: A, B — port formation stage; C — contralateral view after bilateral decompression; D — discectomy stage; E — endoscopic picture of intervertebral disc cavity; F, G — cage installation stage; H — postoperative wounds

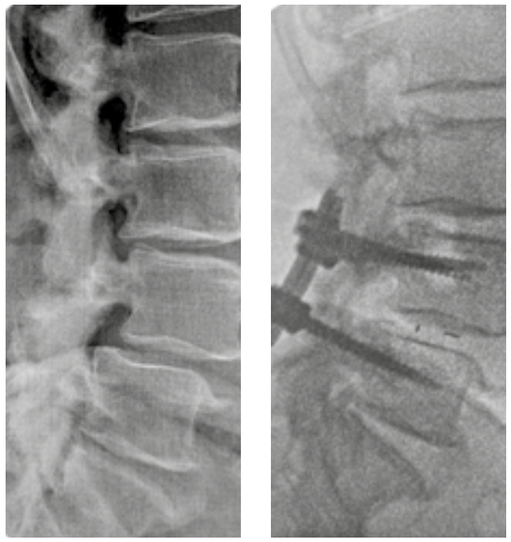


Fig. 8. Radiological images before and after biportal endoscopic interbody fusion and percutaneous transpedicular fixation

The next step is percutaneous transpedicular fixation using the same incisions on the ipsilateral side to install the screws (Fig. 8).

Results and Discussion. Between August 1, 2019, and January 1, 2021, 102 patients were operated on using biportal endoscopic technology (Table 2).

The follow-up period ranged from 6 to 16 months. The average duration of the surgery was the longest in Group 3 and the shortest in Group 2. There was a significant improvement in the dynamics of pain syndrome according to the ODI scale in all three groups. There were no unsatisfactory results according to the Macnab scale in any group. There were 3 cases of linear dural sac damage in Group 1 and 1 case in Group 3. In all cases, the durotomy did not exceed 3 mm and did not require additional treatment. It is noteworthy that all cases of dural sac injury occurred in the first 10 operations in each group. In 1 case in Group 3 there was excessive traction of the passing root during cage placement accompanied by paresis up to 3 points and hypoesthesia, which regressed within 3 months after surgery. No cases of infectious complications were identified.

Table 2. Comparative analysis of indicators of three groups

Category	Indicators		Groups		
			1st	2nd	3nd
General Indicators	number of patients		57	24	21
	duration of surgery, min		54,2±12,1	42,12±6,7	142,5±21,4
	DSA, mm²		317,1±45,69	–	–
Perioperative complication	durotomy		3	0	1
	epidural hematoma formation		0	0	0
	liquorrhea		0	0	0
	damage of neural structures		0	0	1
	surgical-site infection		0	0	0
	NRS, lower back	Before surgery	5,7±1,12	5,32±0,89	7,64±1,32
		One day after surgery	2,4±1,14	2,12±0,96	3,21±0,91
		Через 6 месяцев	1,78±0,73	1,83±0,88	2,34±1,16
	NRS, lower extremities	Before surgery	7,32±1,01	7,87±1,23	6,43±1,76
		One day after surgery	2,3±0,75	1,98±0,67	3,1±0,97
		After 6 months	1,97±0,87	2,11±0,79	2,2±0,85
	ODI	Before surgery	61,43±7,2	55,23±5,74	69,3±8,14
		After 6 months	22,01±3,17	20,12±3,05	28,9±4,38
	Macnab	Excellent	48	19	14
		Good	7	5	4
		Fair	2	0	3
		Poor	0	0	0

Biportal endoscopic surgery can be considered as an alternative to the conventional microsurgical technique of spinal decompression and fusion in the lumbar spine. The use of this technique makes it possible to significantly reduce muscle trauma, achieve sufficient decompression, and reduce the incidence of infectious complications.

Conclusion. For the first time in Russia, clinical experience is presented, the possibilities are evaluated, as well as the safety and the effectiveness of biportal endoscopic spine surgery technology for degenerative pathology of the lumbar spine are proved.

Biportal endoscopic surgery can be considered as an alternative to the conventional microsurgical technique of spinal decompression and fusion in the lumbar spine. The use of this technique makes it possible to significantly reduce muscle trauma, achieve sufficient decompression, and reduce the incidence of infectious complications.

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Application of cellular technologies in the treatment of chronic pain of the lumbar spine

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Abstract. The paper presents the results of clinical testing of autologous cells of the stromal vascular fraction (SVF) mesenchymal stromal cells in patients with deforming spondyloarthrosis of the lumbar spine. The study selected 20 patients aged 45 to 85 years with symptoms of degenerative spondyloarthrosis of the lumbar spine confirmed by radiological methods (CT, MRI, X-ray), 5 men, 15 women, average age 64.7 years with a disease duration of 5 years. Autologous SVF cells were injected into the affected facet joints under the control of an electron optical converter. The introduction of SVF cells did not cause the development of inflammatory allergic and toxic reactions. Patient survey conducted 1 month after the introduction of SVF cells revealed a decrease in the severity of pain syndrome, assessed on a visual analog scale (VAS) and a specialized SF-36 scale ($p<0.05$ on both scales). Patients noted an improvement in functional activity and quality of life associated with the affected facet joints. Positive clinical dynamic was maintained during follow-up up to 6 months. The control magnetic resonance imaging after 6 months revealed no significant differences from the initial examination. Our study showed the safety and good tolerability of the introduction of autologous SVF cells into the areathe zygapophysial (facet) of facet joints. Our study showed the safety and good tolerability of the introduction of autologous SVF cells into the area of the Lumbar Facet Joint Injectionsin patients with severe manifestations of deforming spondyloarthrosis. The obtained results also indicate a significant anti-inflammatory effect of autologous SVF cells of adipose tissue at the early stages of cell therapy.

Keywords: chronic low back pain, regenerative therapy, medicinal signaling or mesenchymal stem cells, platelet-rich plasma, disc injection, lumbar facet joint injections.

Relevance. Currently, the wide application of cell technologies is observed in many branches of medicine: cosmetology, orthopedics, purulent surgery, dermatology, vascular surgery, ophthalmology [1, 2, 3, 5, 8, 9, 10, 15, 18, 21, 22].

Cell therapy is the transplantation of human cells for the replacement or recovery of damaged tissues and/or cells, where the stromal-vascular fraction (SVF) occupies a prominent place.

Stromal-vascular fraction is a heterogeneous universal cell system [3, 4]. The SVF is known to contain endothelial cells (EC), smooth muscle, mural, mesenchymal cells (MC), fibroblasts, macrophages, other stem cell phenotypes [3, 15, 24]. The application of mesenchymal stromal cells (MSCs) was limited due to the traumatic nature of obtaining biological materials from donor areas of the body, in particular from the bone marrow [3, 7, 15, 28, 29]. A group of scientists led by P.A. Zuk [29] in 2001 managed to cultivate and study the properties of multipotent cells isolated from human autologous adipose tissue (AAT), which led to the search for a safe method of obtaining adipose tissue (AT) from patients for the subsequent isolation and cultivation of stem cells (SC) [7, 29].

The mechanism of SVF action is based on a complex interaction of heterogeneous cell population comprising it with the cells of the recipient zone, which leads to stimulation of cell differentiation, angiogenesis, immunomodulatory and anti-apoptotic effects [3, 20] As a consequence, the restoration of damaged tissues takes place. The mechanism of immunomodulatory action of SVF is determined by the presence of MSCs and immune cell population and is based on homing, differentiation into site-specific differentiated cells, on stimulation of tissue SC of the recipient zone and on paracrine effect, which is provided both by direct interaction with SC of the recipient zone and immune system cells (cell-cell contact), and due to the soluble growth factors (GFs) [27]. Mesenchymal stem cells produce a great number of growth factors and cytokines with immunosuppressive, antiapoptotic, antifibrotic and angiogenic actions [17]. Regenerative action of SVF carried out by multipotent stem and progenitor cells, similar to bone marrow MSCs in morphology and immunophenotype, is associated with their ability to migrate to the damage zones [3, 19]. The ability of SVF to stimulate angiogenesis has been proven in many studies and is of particular importance in the treatment of conditions accompanied by ischemia and reduction of vascularization, which is associated, in particular, with an increase in production of such factors of angiogenesis as vascular endothelial FRVEGF, bFGF, HGF, PDGFB, TGFb by SVF cells [3, 6, 15, 16, 25]. The effects of SVF are also determined by the survival of cells after transplantation under ischemic conditions (it is particularly relevant in lipofilling procedures combined with SVF cell autografting). It was noted that MSCs derived from SVF are able to survive under hypoxia and migrate to the peripheral zones of the non-vascularized fat graft, thus having an immunomodulatory effect [11]. Macrophages in AT can be divided into M1 and M2 types according to their activation states. In SVF cell population, more than 90% of macrophages belong to M2 type [24, 16]. M2-type macrophage secretes anti-inflammatory factors such as interleukin-4 (IL-4), interleukin-10 (IL-10), TGF-αand proangiogenic factors (bFGF and VEGF), suppressing the inflammatory response and facilitating vascular network formation.

A special role is played by extracellular vesicles (EVs) (exosomes or microvesicles), being enclosed in a membrane similar to the membrane of the cell itself. The main function of exosomes is the ability to transport information from their donor cells to recipient cells (target cells) [3, 13]. Clinical studies registered at ClinicalTrials.gov are devoted to the application of heterogeneous population of SVF cells in the therapy of autoimmune diseases of the musculoskeletal system and injuries. Current clinical studies demonstrate the safety and efficacy of SVF therapy in humans. The results of clinical trials on the use of SVF in degenerative-dystrophic disc lesions in 15 patients after intradiscal injection under fluoroscopy and one year later demonstrate the absence of side effects, at the 12th month there is an improvement in the dynamic range of motion, with pain syndrome reduction [9]. The use of SVF for articular cartilage injuries of the knee joint in 30 patients during arthroscopic lavage resulted in a subsequent reduction in pain after 25 months. Control diagnostic arthroscopy revealed 3 cases of complete healing, in 7 patients new cartilage covering the defect was observed, in 4 patients the results were regarded as doubtful, in 2 there were no signs of cartilage recovery, in 5 there was a deterioration [18]. In the treatment of staged I-II osteoarthritis of the knee joint, intraarticular SVF injection was performed in 6 patients; one year later, improvement of clinical indicators was confirmed: decrease in pain syndrome and increase in joint mobility, without changes on MRI [8].

In maxillofacial surgery, bone regeneration of the maxillary sinus tissue was confirmed in 6 patients after SVF in combination with calcium-phosphate ceramics. A 6-month follow-up showed an increase in bone density and osteoid density in the biopsies studied (with the addition of SVF), which was not observed in the control group since only the ceramic on the contralateral side was examined, especially in patients who received αtricalcium phosphate.

A match-paired analysis of 6 patients treated bilaterally revealed an increase in bone mass and osteoid volume using microcomputed tomography and

histomorphometric assessments, demonstrating an additive effect of SVF, regardless of bone substitute [22]. For tendinopathies of the achilles tendon, intradiscal injection was performed in 43 cases and follow-up at 15-30 days and 6 months showed an improvement, namely decreased pain syndrome on the VAS, AOFAS, VISA-A scales and questionnaires, and there was no change on ultrasonography after 6 months [26, 5].

When SVF was injected into infected traumatic wounds in 5 patients, diabetic ulcers in 3 patients, scar ulcers in 2 patients, and sarcoidosis in 1 observation 2 weeks later, histology revealed differences in collagen expression, immunohistochemistry revealed higher CD31+ expression in the SVF cell population, and significant differences in wound healing rate in favor of SVF as a percentage [10].

Treatment of systemic scleroderma, ulceration and necrosis of finger phalanges by injection of SVF into the fingers with follow-up for 12 months showed positive dynamics represented by a decrease in finger edema, skin sclerosis, improvement in movement volume, sensitivity and finger strength.

The efficacy of conservative therapy of cartilage defects of the knee joint with the combined intraarticular injection of SVF and platelet-enriched plasm was also noted in the study of O.I. Startseva et al. (2016) [2]. Positive results in the treatment of cartilage defects of large joints were as well reported by other researchers [8, 9, 10,1 8]. One month after the SVF was injected into the joint cavity, the MRI study showed a complete closure of the defect by homogeneous tissue similar in structure to cartilage; in addition, the restoration of intra-articular system homeostasis was recorded as a sharp decrease in inflammatory factors, and as a consequence, the pain syndrome was eliminated [1, 23].

In their study, the authors found that alkaline phosphatase activity was significantly higher in human osteoinduced SVF than in mesenchymal stromal bone marrow cells (MSBMC) when induced for 3 weeks, whereas matrix calcification was 35-fold higher in SVF and 68-fold higher in MSBMC when induced for 6 weeks. In addition, the authors performed gene expression (osteocalcin-specific osteogenic gene, alpha-1 subunit, Runt-related transcription factor 2, osteonectin, osteopontin, bone morphogenic protein-2) on both osteoinduced mesenchymal stem cells of adipose tissue (MSCAT), and on MSBMC, and showed the effectiveness of MSCAT in the restoration of not only bone (in the form of filling intraosseous cysts or for acceleration of bone consolidation in the postoperative period), but also cartilage tissue [12, 14, 15, 21, 29].

The positive impact of cell therapy in many areas of medicine proves the relevance of discovering new ways of application for the treatment and evaluating the effectiveness of using techniques of regenerative therapy for SVF, including minimally invasive treatment of degenerative spondyloarthrosis of the lumbar spine.

Purpose. To evaluate changes in the quality of life in patients with deforming spondyloarthrosis after the use of SVF injections in the region of facet joints.

Material and methods. This work is based on the analysis of the results of treatment of chronic pain syndrome in patients with deforming spondyloarthrosis of the lumbar spine after using SVF injections treated at the 64th Department of Spine Surgery of the Traumatology and Orthopedics Center of The Main Military Clinical Hospital named after N.N. Burdenko during the period 2021-2022. Twenty patients, including 5 men and 15 women aged 45 to 85 years (mean age 64.7), with signs of marked degenerative dystrophic spondyloarthrosis of the lumbar spine confirmed by radiological methods of examination (CT, MRI, X-ray) were selected for the study. The duration of the disease was 5 years. Inclusion criteria:

- primary lumbar spondyloarthrosis with compensated size of the spinal canal and foraminal foramina of the spinal column, with predominant involvement of the arch and facet joints, verified clinically and radiologically;
- the possibility of liposuction;
- written Informed consent.

Exclusion criteria:

- patients with severe degenerative changes of the spinal canal complicated by stenosis;
- severe decompensated cardiovascular, respiratory, hepatic and renal failure;
- autoimmune diseases;
- acute infectious diseases;
- mental illnesses;
- allergy to drugs for local anesthesia;
- use of corticosteroid drugs in the preceding 4 weeks.

Fat tissue was obtained by liposuction from the anterior abdominal wall and processed using a standard technique. The manipulation was performed under operating room conditions. Tumescent anesthesia with Klein's solution was administered, and after 30 minutes, fat tissue was collected into a syringe of approximately 150-200 ml. The duration of the procedure averaged 30 to 50 minutes, then autologous cells of adipose tissue were processed using the Smart X adipose tissue separation kit "DongokooBio&PharmaCo., Ltd." (Korea), registration certificate № RD-30326/79431 dated 06.12.2019. The obtained adipose tissue was mixed with collagenase solution, then incubated with shaking 200 rpm. 20 minutes, after enzymatic treatment — sequential centrifugation of the lipospirate in order to remove the enzyme and increase the concentration of MSCs. The procedure of SVF extraction from the lipospirate took 60 minutes. After completion of the treatment, the regenerative cells of the adipose tissue were separated into 2 parts: The 1st part of the cells is used to count their number, assess viability, and perform sterility tests; the 2nd part of the cells is placed in a sterile syringe for subsequent injection.

Injection of SVF cells was performed by a doctor in the operating room under the radiation control of the EOC. The surgical field was treated three times with 70% ethanol solution. Cannulas (1.0-1.2 mm in diameter, 120 mm in length, 0.1-0.2 ml volume) were placed in the projection of trigger zones, determined by palpation before the procedure, and autologous regenerative cells obtained from the patient's adipose tissue were injected into the area of facet joints. 1 injection of SVF was made at one level.

When analyzing clinical efficacy, we used assessment of pain syndrome severity by visual analogue scale (VAS) of pain and evaluation of quality-of-life indicators by the scales of SF-36 questionnaire in all 20 patients. This questionnaire evaluated patient's satisfaction, functional state of motor and emotional sphere, and daily activities. The questionnaire was filled out independently by the patient before the procedure and at 1, 3, 6 months after it. Statistical methods were used to process the material: arithmetic mean (M) and error of mean (m) were determined in the 2 groups. For all analyses differences were considered significant at $p<0.05$.

Results. According to radiological methods of examination (n=20), patients with lumbosacral pain showed signs of osteochondrosis stage 2-3 in 100% of cases, spondyloarthrosis in 85% of cases, subchondral osteosclerosis in 95% of cases, disc protrusion and extrusion in 90% of cases. All patients included in the study were examined 1, 3, and 6 months after SVF administration. No significant differences were found on control examinations after 6 months. A single injection of SVF cells into the region of the facet joints was accompanied by a gradual decrease in pain syndrome as assessed by the VAS and SF-36 scales (quality of life assessment), with 16 of 20 patients noting a decrease in pain already one month after cell introduction ($p<0.05$), which persisted up to 6 months of follow-up. According to VAS the severity of the pain syndrome before the procedure during the pain attacks was 8,9±1,7 ($p<0,05$) points, which corresponds to severe pain. In 1 month after SVF introduction, pain relief was observed, the values decreased to 5.4±2.1 ($p<0.05$) points, corresponding to moderate/weak pain, and gradually decreased during the whole period of observation, reaching a twofold decrease by 6 months from 8.9±1.7 points to 2.85±1.25 ($p<0.05$), corresponding to mild pain.

The analysis of patient questionnaire on the SF-36 scale revealed the following: Physical Functioning (PF) — 44.5±21.14 points; Role-Physical Functioning (RP) — 13.3±23.34 points; pain intensity, Bodily Pain (BP) — 23.5±14.75 points; General health (GH) — 56.6±20, 55 points; Vitality (VT) — 45.5±15.03 points; Social Functioning (SF) — 51.8±25.78 points, Role-Emotional functioning (RE) — 42.2±40.73 points, Mental Health (MH) — 53.8±16.33 points. Questionnaires 1, 3 and 6 months after SVF injection revealed improvement of quality-of-life indicators: patients noted significant improvements in self-care and physical activity. The physical health indicators of PF improved by 46.3%, RP by 39.7%, BP by 38.7%, and GH by 39.3% ($p<0.05$). Psychological health of patients VT improved by 34,3%, SF — by 33,4%, RE — by 37,2%, MH — by 32,3% ($p<0,05$), which can be regarded as decrease of pain syndrome, increase of physical activity and general quality of patients' life.

Conclusion. The results of this study demonstrated the safety and good tolerability of intra-articular injection of autologous SVF adipose tissue cells in patients with lumbar spondyloarthrosis. The method can be considered as one of the ways to prevent further progression of the disease, and in the case of severe lesions such therapy has the potential to help reduce pain and other manifestations of spondyloarthrosis, thereby improving the quality of life. Further studies involving controlled, randomized clinical trials with long-term prospective follow-up are needed to confirm these assumptions, also to confirm the effects of cellular material on the structure of the facet joints and surrounding tissues by radiological examination and morphological evaluation.

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Selection criteria for patients with hepatocellular carcinoma for liver transplantation

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Abstract. The paper considers the selection criteria for liver transplantation for patients with hepatocellular carcinoma (HCC). Liver resection is an effective method of radical treatment in the early stages of HCC. However, severe liver cirrhosis precludes this method of therapy. For these patients, liver transplantation is a good alternative. The article discusses the problem of correct selection of patients for liver transplantation. Best practices in assessing various criteria for liver transplantation are described. Statistical data are provided. There are also examples of studies that analyze additional factors used as extended criteria for liver transplantation: AFP, PIVKA, the effectiveness of locoregional therapy. The article focuses on neoadjuvant therapy, presents the results of global research on neoadjuvant therapy, and emphasizes their importance.

Keywords: liver transplantation, neoadjuvant therapy, inclusion criteria, hepatocellular carcinoma, TACE, systemic therapy.

Introduction. Liver cancer is a significant problem of modern oncology. Hepatocellular cancer (HCC) remains the fourth most frequent cause of cancer death worldwide [1]. This type of cancer ranks 11th in terms of morbidity, and its prevalence is steadily growing in the Russian Federation. The increase in the incidence rate over the last 10 years reached 32%. The prevalence of liver cancer in Russia as of 2019 is 6.2 per 100,000 population.

Liver resection is a highly effective method of radical treatment of HCC at early stages [2]. However, this type of cancer is usually associated with the presence of marked liver cirrhosis, which significantly complicates the management of such patients and limits the possibilities of radical liver resection. With adequate selection of patients, liver transplantation can be the method of choice for patients with HCC, since both the primary liver tumor and the precancerous disease (cirrhosis) are eventually eliminated [3]. World experience shows that about 25% of all liver transplants are performed due to HCC [4].

When selecting candidates for transplantation in patients with HCC, transplantologists prefer follow by the Milan criteria developed in 1996 by V. Mazzafero et al.: tumor lesion limited by a solitary nodule less than 5 cm in diameter or three nodules of less than 3 cm each [5]. These criteria are accepted by most transplantation centers and are positioned as a basis for determining indications for orthotopic liver transplantation (OLT) in patients with hepatocellular carcinoma [4, 6, 7].

Orthotopic liver transplantation performed in accordance with the Milan criteria predicts a 5-year overall survival (OS) of at least 75%. Some publications demonstrate results of 5-year OS of not less than 75% and recurrence-free survival (RFS) — at the level of 90% in transplantation according to the Milan criteria [8, 9].

However, the realities of clinical practice are such that most patients seek help when the tumor process has already gone beyond the Milan criteria. Studies over the past 15 years have shown that when determining indications for liver transplantation, oncologic criteria can be significantly expanded, and the results of OLT can be comparable with the rates of 5-year survival in patients operated on within the framework of the Milan guidelines [7]. Some of them are presented below.

Extended transplantation criteria. Among the extended criteria, the most popular are the University of California liver transplantation criteria: solitary tumor node ≤6.5 cm or 2-3 nodes, the largest of which is ≤4.5 cm, with the total size of tumor foci ≤8 cm. According to the authors, transplantation within the given criteria provides 5-year OS of 72.4% [10].

The authors of alternative criteria ("up-to-7 criteria") have received 5-year OS, equal to 71.2%, if transplantation within the limits of the total size of tumor foci up to 7 cm. The number of tumor foci should be ≤7, without microvascular invasion [11].

Our colleagues at the University of Tokyo also had high results: 3-year RFS of 94% when transplanted in the limits of 5 tumor foci, each ≤5 cm [12].

A group of scientists led by N. Kneteman in liver transplantation with one focus up to 7.5 cm or several foci ≤5 cm each managed to achieve 4-year OS of 82.9%, 4-year RFS of 76.8% [13].

The development of oncology has led to the fact that in recent years scientists around the world have started to pay attention not only to the size and dissemination of the initial foci, but also to the biological features of the tumor.

V. Mazzafero et al. emphasized that tumor morphology and biology are different, and not always one corresponds to the other [14].

For example, M. Grąt et al. added one parameter to the California criteria — AFP (alpha-fetoprotein) level — and obtained a 5-year OS equal to 100% in patients with AFP <100 ng/ml [15]

Besides M. Grąt, AFP as an additional criterion was used by other authors, including Q. Lai et al. (2012) (total tumor size ≤8 cm, AFP ≤400 ng/mL; 5-year OS of 74.4%); S. Toso et al. (2015) (total tumor volume ≤115 cm3, AFP level ≤400 ng/mL; 4-year OS of 74.6%); C. Kwon et al. (2007) (any number of foci ≤5 cm each, AFP ≤400 ng/mL; 5-year OS, 79.9%) and other authors [7, 16-18].

Another parameter taken into account is PIVKA-II (protein induced by vitamin K absence or antagonist — II). For example, a group of scientists led by Y. Takada used this parameter along with taking into account the spread of tumor process and got 5-year OS rate of 87% under the following conditions: up to 10 tumor foci ≤5 cm, PIVKA-II ≤400 mAU/ml [19].

The above parameters are chosen by transplantologists around the world for a reason: it is a useful tool to assess the aggressiveness of tumor tissue. Currently, oncologists and transplantologists are actively discussing another parameter — the result of dynamic follow-up after locoregional or systemic neoadjuvant therapy. It is especially difficult to evaluate and introduce this parameter into the criteria due to the fact that there is no consensus in the world literature on the necessity of therapy before transplantation.

Treatment of HCC before transplantation. The experience of many clinics shows that, in spite of the desire to meet the Milan criteria, in reality there are at least 20-30% of patients who undergo surgery at a later stage [7], because the average stay on the transplant waiting list (TWL) can range from a few months to 1.5 years. The length of stay on the TWL varies depending on the transplant center. The solution could be to treat the cancer preoperatively with bridge or down-staging therapy.

Bridge therapy — neoadjuvant treatment of HCC in patients within the Milan criteria, which aims to prevent tumor progression.

Down-staging therapy — treatment of HCC in patients outside the Milan criteria, which aims to lower the stage of the tumor process and bring it into the transplant limits.

Currently, there is no indication in the clinical guidelines for prescribing treatment prior to liver transplantation. The necessity of prescribing this type of treatment has been extensively discussed in the international medical community.

The following theoretical premises in support of treatment are most commonly stated in the literature:

- Antitumor treatment prior to transplantation reduces the percentage of exclusion from liver TWL due to the tumor progression beyond the criteria (20);
- reducing the tumor burden can improve long-term results after transplantation, including reducing the rate of tumor recurrence [21];
- antitumor treatment before transplantation can play a role in identifying patients with aggressive tumors and the risk of early progression [22].

Many papers have been published, but there is no unequivocal opinion on the appropriateness of prescribing antitumor treatment prior to transplantation. There is also no consensus on the type of therapy prior to transplantation.

A wide arsenal of methods is presented in modern works: radiofrequency ablation (RFA), transarterial chemoembolization (TACE), targeted therapy, but most often combinations of these methods are used [23-30].

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A group of scientists led by C. Tan published a paper entitled "Bridge Therapy — Is Bridge Therapy a Bridge to Nowhere?" in which the authors discussed the problem: Is bridge therapy in fact necessary? [28].

65 patients with HCC participated in the study, which was conducted by C. Tan and his team, 29 of them did not receive therapy before transplantation, 36 patients received various therapies before transplantation: 17 (47.2%) patients received TACE as the only treatment and 10 (27.8%) patients received RFA also as the only treatment. The remaining patients received a combination of TACE and RFA.

In the group of patients who did not receive bridge therapy, transplantation was performed in 19 (65.5%) patients, the rest dropped out of TWL. A three-year OS was 80%, 3-year RFS — 77%.

In the group of patients receiving neoadjuvant therapy, 20 (55.6%) patients underwent transplantation. The three-year OS was 84% and the 3-year RFS — 71%, with a mean time in TWL of 180 and 291 days in the no-treatment and neoadjuvant group, respectively.

Thus, it can be noted that there were no significant changes in OS (p=0.862) and RFS (p=0.585), however, it is worth considering that the average waiting time in TWL for patients who received neoadjuvant therapy was 1.6 times longer.

Equally notable research was carried out by M. Ravaioli and his colleagues, who investigated the effect of down-staging therapy on OS and progression-free survival (PFS) after transplantation [29].

The patients were divided into 4 groups. Group 1 included patients who received down-staging therapy with an effect (n=65). Group 2 included patients who were given down-staging therapy, but the effect was not achieved (n=30). Group 3 included patients who could not receive down-staging therapy due to the severity of their condition (n=27). Group 4 consisted of patients whose disease progression at the time of inclusion in the study was within the Milan criteria, for which reason these patients did not receive therapy (n=186). The groups were homogeneous in composition. TACE, RFA, and ethanol injection were used as treatment modalities.

Five-year OS was 64% in Group 1, 60% in Group 2, 66% in Group 3, and 75% in Group 4 (p — non-significant).

The probability of recurrence was 7.6% in Group 1, 20.9% in Group 2, 31.6% in Group 3, and 30.4% in Group 4 (p<0.001).

Thus, there is no significant difference in OS between the groups, but the recurrence rate is lower for patients in the Milan criteria and for patients with successful antitumor treatment.

A research group led by V. Mazzaferro conducted a prospective study that reflects the importance of combining effectively implemented down-staging therapy with liver transplantation [30].

74 patients with HCC participated in the study. All of them received locoregional down-staging therapy; 22 patients dropped out of the study due to disease progression, 7 patients for other reasons; 45 patients were randomized into 2 groups: 23 underwent OLT, and 22 were in the control group and were under dynamic follow-up, receiving no antitumor treatment.

The 5-year RFS was 76.8% in the OLT group compared to 18.3% in the control group; the 5-year OS was 77.5% in the OLT group compared to 31.2% in the control group.

The findings strongly support active treatment: performing OLT when the transplantability criteria are achieved.

Conclusion. The therapy of HCC requires, above all, a multidisciplinary approach. It is necessary to involve specialists from different fields of medicine: transplantologists, oncologists, infectious disease specialists, hepatologists, surgeons.

The use of donor organs should be as effective as possible not only for medical and ethical reasons, but also due to the fact that patients with liver transplantation who are on immunosuppressive therapy have limited opportunities for antitumor treatment in case of progression. In this regard, it is particularly important to develop optimal criteria for liver transplantation, taking into account not only the extent of the tumor process, but also the biological features of the tumor.

The length of stay in TWL is another limiting factor for transplantation. The question of the appropriateness of prescribing therapy prior to liver transplantation is particularly relevant. Currently, there are no recommendations for prescribing bridge therapy, and there are no criteria for which down-staging therapy should be considered. There are still many unresolved questions. Every year new drugs and their combinations are registered. Every year we move further and further in the search for an individual and optimal approach toward the therapy for each HCC patient.

Until recently, sorafenib was the only drug that showed efficacy in first-line therapy of HCC. As of August 16, 2018, lenvatinib has been registered by the FDA as an alternative to sorafenib [31]. In a 2019 randomized clinical trial (IMBrave150), the combination of atezolizumab (anti-PD-L1) + bevacizumab demonstrated a significant increase in progression-free and overall survival compared with sorafenib [32]. The atezolizumab + bevacizumab regimen demonstrated high direct antitumor activity with 35% objective effects, where every third case had a complete effect. The atezolizumab + bevacizumab regimen has been recommended by the FDA, EMEA, and several other national professional societies in the first-line treatment of advanced HCC since 2020. Nivolumab may also be a good alternative as first-line therapy in cases of intolerance to lenvatinib, sorafenib, and bevacizumab.

Registration of new regimens opens up additional opportunities for clinical trials of neoadjuvant regimens in patients in TWL.

In the shortest possible time, it is crucial to develop clear criteria for the selection of patients for liver transplantation, the optimal regimen of therapy, which would not only keep the patient in TWL, but also allow to improve the survival rate after it.

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Effectiveness of endoscopic operations in vertebrology

Literature review

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Abstract. In this literature review, an attempt was made to describe the main possibilities and limitations of arthroscopic spine surgery. The description is organized according to topographic principle, for each region of the spine (cervical, thoracic, lumbar).
Arthroscopic interventions in vertebrology are a set of methods that are promising and gaining popularity. At present, the main scope of their application (and indication for treatment as well) is degenerative diseases of the spine that are associated with nerve structures' compression. Arthroscopic methods allow, according to present data, to achieve better functional results than conventional 'open' surgical methods, including lower pain level at the postoperative period.
The main issues for development of the methods are as follows: minimizing the working parts of the endoscope to be used for interventions at the cervical spine; avoidance of anatomic restrictions for operations on the thoracic spine; expanding the possibilities and indications for the method.

Keywords: spine surgery, endoscopy, mini-invasive surgery, literature review.

Introduction. Endoscopic interventions are a consequence of the development of vertebrological surgery and a result of the desire to reduce a surgical treatment traumatism. Currently, such interventions are performed in many countries including Russia, and more and more attention is given to the development of endoscopic techniques.

In this review an attempt is made to describe the effectiveness of the endoscopic interventions which will help the clinicians and researchers to form their own opinion about these techniques. The development of minimally invasive endoscopic techniques in orthopaedics was initially built around the problem of herniated intervertebral discs in the lumbosacral spine. The first attempts to use the endoscope in spine surgery were made in the 1970s and are attributed to P. Kambin and S. Hijikata [1]. However, the equipment of those times was highly problematic due to its technical imperfection, namely, scarcity of incoming visual data, which forced vertebrologists to resort to discography [2, 3].

There have been attempts to perform laser decompression [4], but full control of both the instrument and the operating field as a whole became available only after the use of relatively modern endoscopes started. Thus, in 2001, it became possible to perform foraminal decompression of nerve roots [5]. The next step forward that predetermined the development of endoscopic vertebral decompression was the discovery of the "safety triangle" or "safe working area" [6].

Historically, a bilateral biportal access was used for such interventions, resembling the arthroscopic knee joint access, but later, as a result of technical development, a unilateral uniportal technique was proposed. P. Kambin et al. published the results of treatment of 56 patients with biportal access and 116 patients with uniportal access [7].

Subsequently, the intradiscal technique ("in-out-technique") was abandoned, the intervertebral disc and its fragments began to be resected under full visual control. In 2005, M. Schubert and T. Hoogland published the results of the treatment of 611 patients (2-year follow-up of 558 of them). [8] — endoscopic decompression interventions began to become routine and widespread surgical treatment methods.

Material and methods. A literature search was conducted on January 07, 2021, using the PubMed database for the MeSH terms "spine" and "endoscopy." The depth of the search was 5 years, from 2017 to 2022. Documents relevant to the topic of the review were selected, and secondary citation sources were additionally analyzed.

The following types of documents were considered according to PubMed indexing: Books and Documents; Case Reports; Classical Article; Clinical Study; Clinical Trial; Comparative Study; Controlled Clinical Trial; Meta-Analysis; Multicenter Study; Observational Study; Randomized Controlled Trial; Review; Systematic Review.

General nomenclature. The growing diversity of interventions performed as part of minimally invasive spine surgery prompted the AO «Spine» to develop an appropriate nomenclature, which was then adopted on the basis of the 24 opinions of the leading participants and opinion leaders of the organization [9, 10]:

- The first term is "corridor" — localization of access (anterior, posterior, transforaminal, etc.).
- The second term is an indication of the type of intervention (endoscopic).
- The third term is the section of the spine (cervical, thoracic, lumbar).
- The fourth term is the actual type of intervention (discectomy, foraminotomy, decompression, and others).

Examples of names of interventions corresponding to this nomenclature:

- Transforaminal endoscopic lateral recess decompression.
- Posterior endoscopic cervical foraminotomy.
- Transforaminal endoscopic thoracic discectomy [9, 10].

Despite the obvious convenience of this nomenclature, in our opinion, it is more appropriate to structure the review according to the anatomical-topographic principle — considering each section of the spine separately — for the convenience of reading, perceiving, and using this work.

The cervical spine. Efficiency of pain reduction. K.H. Yu et al. [11] presented data on the results of decompression performed at the cervical level from dorsal access. The results of 1-year follow-up showed the following dynamics: pain syndrome measured by numerical rating scale (NRS) scale decreased from 6.94±0.75 to 2.88±1.22 (the difference is statistically significant); by mJOA (modified Japanese Orthopaedic Association) scale improved from 8.50±1.12 to 14.50±1.46.

Complications. K.H. Yu et al. [11] reported the absence of significant complications (including dural damage, bleeding, infectious-inflammatory and other) in 16 patients with dorsal endoscopic decompression during 1 year of follow-up.

The thoracic spine. The thoracic spine is difficult from the point of view of endoscopic surgery for a number of reasons described in the relevant section. The "priority" nosology for which thoracic decompression is indicated and predominantly performed is yellow ligament ossification rather than intervertebral disc herniation.

Efficiency of pain reduction. Z. Xin et al. [12] described the results of translaminar endoscopic resection of the yellow ligament with decompression of the spinal canal in the thoracic spine. Thirteen patients with 23 levels of yellow ligament ossification and intervention showed improvement from 3.54±1.26 to 9.07±1.48 on the mJOA scale. No serious complications were registered, except for 1 intraoperative dural injury and 1 case of pain syndrome at the surgical site (managed by administration of glucocorticosteroids).

Z.Z. Li et al. [13] reported the treatment results of 15 patients with yellow ligament ossification in the thoracic spine (17 operated segments). Statistically significant improvement was achieved according to the NRS, Nurick, ODI (Oswestry Disability Index), and mJOA scales, with an average of 78.3% functional recovery compared to the healthy level. The maximum dynamics of pain syndrome reduction and improvement of functional results was achieved by the end of the 1st year of follow-up. No statistically significant changes were observed between 1 and 2 years after the intervention.

Complications. Z.Z. Li et al. [14] analyzed the results of spinal cord decompression in the thoracic spine (the compression was caused by calcification of the yellow ligament). A rather high incidence of complications was revealed: 5 cases of dural sheath injuries were found in 14 patients, which may be related to the close attachment of the aforementioned to the walls of the spinal canal in the thoracic section.

The lumbosacral spine. Lumbosacral spinal canal stenosis caused by a herniated intervertebral disc is obviously one of the central clinical problems that minimally invasive spine surgery is designed to deal with.

Efficiency of pain reduction. M. Avellanal et al. [15]

reported that when performing transforaminal decompression of the lumbosacral spine (levels L4-L5, L5-S1), many (54%; 95%, CI: 34%-74%) patients with operated spine syndrome reported more than a 50% reduction in pain as measured by the NPRS (numeric pain rating scale)-11 at 1-year follow-up.

C.H. Park et al. examined the dynamics of pain after minimally invasive interlaminar decompression of the spinal canal for up to 6 months. The pain reduction with high statistical significance ($p<0.001$), as measured by the ODI, ZCQ (Zurich Claudication Questionnaire), and NRS scales, was observed both in the earlier (2 weeks) as well as by the end of the indicated follow-up period [16].

Complications. Recurrent herniation of the intervertebral disc. According to C. Park et al. [17], in case of transforaminal endoscopic decompression of the lumbar spine in which the intervertebral disc was resected, the incidence of recurrent intervertebral hernia formation reached 11% (209 patients out of 1,900 who underwent treatment). Recurrent herniation of the intervertebral disc occurred within 24 hours in 27 of patients; overall, it occurred predominantly within 2-30 days after surgery (76 patients out of 209).

The authors noted that the smaller the size of the operated disc, the higher was the incidence of this complication (differences between discs of different sizes were statistically significant, $p=0.04$). The influence of other factors: age, body mass index, presence of diabetes mellitus and arterial hypertension, localization of the protrusion/extrusion (central, paramedial, or foraminal), degree of Modic changes, and presence of spondylolisthesis — was not statistically significant.

Other complications. According to M. Avellanal et al. [15], only 6 (25.0%) of the 24 studied patients had complications, but they were limited to minor pain syndrome in the operation area and lower extremities, lasting less than 4 days from the time of surgery and managed with oral administration of NSAIDs (Non-steroidal anti-inflammatory drugs).

L. Chen et al. attempted [18] to identify risk factors for reoperation after endoscopic resection of lumbosacral intervertebral disc herniation. The median follow-up period was 1685 (523 to 3923) days. Unsatisfactory outcome (fair/poor MacNab score) was associated with pronounced protrusion of the disc fragment into the lumen of the spinal canal ($p<0.001$), a high degree of degenerative changes in the disc ($p=0.047$), the pathology in the upper lumbar section ($p=0.026$), long-standing preoperative symptoms ($p<0.001$), and outside-in technique, which was a comparatively older technique ($p=0.020$).

Atypical use of endoscopic decompression techniques. L. Chen et al. presented the experience of treating 10 patients with cauda equina syndrome caused by the formation of intervertebral hernia. All patients showed improvement of neurological functions with significant regression of pelvic organ dysfunctions during the 1-year follow-up period [19], which allows to consider endoscopic decompression as an effective method, despite the current paucity of data.

Comparison with "open" methods. The question about the place of the developing endoscopic surgery among other vertebrological interventions is consequential and of interest to many researchers. A. Seiger et al. [20] proposed a protocol for studying both clinical and economic efficiency of endoscopic interventions using a comparison of percutaneous transforaminal endoscopic discectomy (PTED) and its analogue — "traditional" open discectomy with dorsal stabilization. Considering the emergence of this and other protocols, a large number of publications with similar methodology can be expected in the future, which, in turn, will allow the creation of high-quality systematic reviews and metaanalyses.

M. Kim et al. in 2018 published a meta-analysis [21] devoted to this issue, based on data from 7 works and a total of 1254 patients. The results of percutaneous endoscopic discectomy in the lumbar spine (PELD) and open discectomy (OLD) for intervertebral disc herniation of the corresponding localization were compared. The following results were obtained:

- Comparison of outcomes using the MacNab scale showed no statistically significant differences (odds ratio = 1.02; 95% CI=0.71-1.49; $p=0.90$).
- The average ODI score was significantly lower in the PELD group than in the OLD group (14.54% and 16.52% respectively, $p=0.05$), indicating a better functional outcome of endoscopic interventions compared to "classic" (open) ones.
- The statistical difference in complication incidence between the 2 types of interventions was not statistically significant (OR=0.72; 95% CI=0.20, 2.62; $p=0.62$).
- The frequency (risk) of reoperation was also not statistically significantly different (OR=1.45; 95% CI=0.89, 2.35, $p=0.13$).
- The time of endoscopic interventions was statistically significantly ($p<<0.01$) lower than that of open interventions: on average, 55.84 and 83.99 minutes, respectively.
- The hospital stay duration for endoscopic interventions was shorter than for open interventions ($p<<0.01$, 2.69 and 7.47 days, respectively).

Efficiency of anesthesia. Y. Zhu et al. reported the advantages of epidural compared to local anesthesia in reducing pain syndrome during transforaminal endoscopic decompression of the lumbosacral spine in patients older than 65 years: during the entire follow-up interval (from the operation to week 1 inclusive), pain syndrome with epidural anesthesia was significantly lower than with local anesthesia ($p<0.001$), while clinical results (including complication rate) were comparable [22]. However, there have been earlier results indicating both high efficiency of epidural and combined anesthesia compared to local anesthesia, and a relatively higher rate of complications. It is worth noting that more than 90% of outcomes at 1 week can be classified as excellent/good outcome [23].

Issues and possible directions for further development. To date, the main area of application of endoscopy in vertebrorology remains "classical" decompression interventions on the lumbosacral spine. The limitations to the use of this technique today are primarily in the cervical and thoracic spine [24].

For example, endoscopes have already been designed to work on the cervical spine, but the size of the working parts of the endoscope becomes more crucial in the cervical spine than in any other section. In the cervical section, there are special requirements to minimize the size of the surgical instrumentation due to the corresponding size of anatomical structures in both children and adults. At the same time, any uniportal endoscope (gradually becoming the de facto standard) must have four channels: for the instrument, for illumination, irrigation and aspiration. For their full-fledged development it is necessary to solve the issue of further minimization, otherwise the tissue damage inflicted during the installation and operation of the endoscope can be unjustifiably high [24].

Due to the small size of the cervical vertebrae and their structural elements, endoscopic work is extremely complicated in terms of intraoperative anatomical orientation. A possible solution is to switch (at least partially) to ventral endoscopic approaches, however, as of today, this issue is still waiting to be studied [24].

The specifics of work on the thoracic spine, meanwhile, are slightly different. The main feature is the shape of the vertebrae with minimal spaces between them, allowing the instrument to be inserted and the surgical approach to be performed. As a result, there is a necessity to remove a significant volume of tissue already at the stage of access, which increases the risk of dural sheath damage, which in turn will require transition to open, at this time, revision intervention [24].

An additional "aggravating factor" is the position of the medial edge of the scapula close to the vertebral column above the level of Th5-Th6, which in some cases does not allow placing the endoscope [24]. Finally, in the thoracic section of the spinal cord and its membranes are located very close to the walls of the spinal canal and the structures forming it, in particular the vertebral arches, and the risk of its damage is rather high [24].

Despite the listed limitations, decompressive endoscopic surgeries at Th5-Th6 and distal (caudal) levels have already been developed and introduced [24].

Summary and Conclusions. Based on the results of this brief review, we can conclude that endoscopic interventions (at this stage mainly pursuing decompressive goals in degenerative-dystrophic spinal pathology) are characterized by better functional results compared to "classic" open techniques with a similar incidence of complications. Studying the experience gained in performing this class of surgeries is justified, as well as a wider spread of such approaches.

At the same time, today there are significant methodological difficulties in the complex assessment of research results. For example, some researchers use different scales in assessing both pain syndrome and neurological outcomes in general, which does not allow to fully summarize the current volume of data accumulated in the form of a meta-analysis or similar researches.

In general, we can conclude that endoscopic surgery as a part of the spine surgery is a promising trend characterized by favorable results. Further study of long-term results and implementation of these techniques in Russian medical organizations is required.

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Biportal endoscopic surgery for degenerative diseases of the lumbar spine

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Abstract. Biportal endoscopic surgery is a minimally invasive innovative method of treatment, where two ports are used, one for visualization, the other for surgical instruments. In this article we describe the biportal endoscopic technique for laminectomy and discectomy, as well as discuss the features of these interventions in degenerative diseases of the spine.

Keywords: endoscopy, lumbar degenerative disease, minimally invasive surgery.

Introduction. Minimally invasive surgical techniques in the treatment of degenerative diseases of the lumbar spine reduce surgical trauma, reduce blood loss, and allow patients to recover from surgery faster [1-3]. In addition, minimally invasive procedures are associated with less muscle damage and fewer complications, which is highly crucial for stabilizing the spine and locomotor function [4, 5].

The first attempts at endoscopic surgery on the lumbar spine date back to the early 1980s [6, 7]. However, only in the last two decades this technique has become a breakthrough and capable of replacing microsurgical techniques, especially for degenerative diseases of the lumbar spine.

Asian spinal surgeons have made a major contribution to the widespread use of endoscopic techniques and have conducted extensive clinical and scientific work on this topic. A PubMed search of scientific publications on endoscopic surgery of the lumbar spine shows that more than 80% of works are published in Asian countries [8]. It has been shown that even with a certain trajectory of training in endoscopic techniques, once a surgeon has mastered them, he can achieve comparable and sometimes better clinical results than in conventional microsurgical operations [1, 8, 9]. Moreover, it is becoming possible to perform part of such surgeries on an outpatient basis [10].

Biportal endoscopic surgery is a minimally invasive technique using endoscopic and arthroscopic instrumentation with two ports: one for imaging and one for surgical instruments [11-13]. There is also monoportal endoscopic spine surgery, which brings good results, but still has some limitations in handling surgical instruments around the neural structures due to the small working space [14].

In single-port endoscopic surgery, direct posterior decompression is performed by resection of the arch and the medial part of the articulation of the lower and upper articular processes, which can be performed using poste-

rior or posterolateral access [9]. However, it is extremely difficult to apply microscopic instruments through the uniportal endoscopic corridor, and there are significant difficulties for visualization.

In this article, we describe the biportal endoscopic technique for laminectomy and discectomy and discuss the features of these interventions.

Biportal endoscopic surgery for the treatment of degenerative diseases of the lumbar spine has shown substantial positive results.

Technical nuances, surgical results, and details of the method are described in this article based on the literature and our own experience.

Peculiarities of the surgical technique. Position of the patient on the abdomen, moderate flexion. Fluoroscopic control is performed to determine the correct level. Generally, for intralaminar (posterior) access, two entry points are made: approximately 1-1.5 cm above and below the interdiscal space along the interpedicular line. For transforaminal (posterolateral) access, points are made along an imaginary line connecting the ends of the transverse processes above and below the foramina. To ensure free outflow of irrigation fluid, a linear fascia dissection about 7 mm wide is performed with a scalpel.

The multifidus muscle is atraumatically (bluntly) separated from the bone, with a sequential dilator placed in the area of the facet joint. The correct position of the instrument is verified by biplane fluoroscopic control [15]. When intralaminar access is performed, the working introducer is inserted through one endoscopic port, and another, wider working port for instruments is installed with the "split" of the muscles that straighten the spine and the multifidi muscles. The multifidus muscle is separated from the arch to prepare the working space. The expander is inserted into the intermuscular septum, after which the multifidus muscle is separated from the arch. Minor bleeding from the muscle is controlled with a radiofrequency coagulator.

One of the main advantages of this technique is the atraumatic creation of the working space between the multifidi muscles and the prevention of trauma due to crushing and excessive traction occurring in other conventional minimally invasive surgeries. In addition, we can achieve a clear and wide field of view in the epidural workspace, preserving the epidural fat and vessels. Such good visualization is obtained from the workspace used as a joint cavity as in arthroscopic surgery.

Common instruments such as drills, Kerrison cutters, discotomes, curettes, spoons, etc. used in open surgery are inserted through the working port.

Bilateral decompression is performed first at the site of the pathological lesion. The hypertrophic facet joints, the arch and the thickened yellow ligament that compress the nerve structures are selectively removed safely by drilling, and then a curette or excisional instruments can be used to "free" the nerve structures. Bilateral decompression can be performed through a unilateral opening in the plate. For bilateral decompression, a laminotomy is performed starting at the spinolaminar junction, undercutting the base of the spinous process. Partial resection of the base of the spinous process allows free passage of the endoscope from the contralateral side in the spinal canal. Once exposed, the yellow ligament is separated from the contralateral lamina with a blunt dissector. When we pass to the contralateral side, the endoscope is inserted dorsally in relation to the yellow ligament, preserving the integrity of the dura to protect the nerve structures. After the contralateral side is completely exposed, the yellow ligament is separated from the dura mater and removed with a curette and Kerrison cutters. If there is dense adhesion between the yellow ligament and the dura mater, we do not remove it aggressively because the dura mater may rupture during the procedure. Bone decompression of the facet joint and the lateral pocket is performed cranially or caudally with a drill.

A medial partial facetectomy is performed so that the dorsal part and the integrity of the facet joint are intact [4]. After sufficient bony decompression, further delicate resection of the remaining yellow ligament is performed using a curette or curved laminotomes and discotomes to completely "free" the nerve structures [16].

Decompression of the lateral pocket requires gentle manipulation with Kerrison cutters to avoid rupture of the dura mater. A small-diameter high-speed drill can be used for safer decompression of the lateral pocket stenosis.

It is possible to obtain a clear image without damaging the epidural fat and vessels by continuous irrigation with a saline solution below or around 30 mmHg, with no pump, using a free outflow of saline solution.

Usually, epidural fatty tissue and vessels are damaged during microscopic, microendoscopic and single-port endoscopic surgeries, which leads to postoperative scarring and fusion of dura mater with bone tissue, which, in turn, potentially causes postlaminectomy syndrome [11]. It is possible to avoid an excessive increase in epidural hydrostatic pressure and subsequent excessive increase in intracranial pressure by maintaining a constant free outflow of irrigation fluid through the working portal [4].

Laminotomy and flavectomy can be performed in the same way as microscopic surgery, and epidural bleeding can be stopped more effectively using a low voltage radiofrequency bipolar coagulator with good visualization and continuous irrigation with saline solution.

For foraminal stenosis, it is necessary to create a working space by careful dissection with a blunt dissector and radiofrequency coagulator to avoid neuralgia of the spinal ganglion and exiting nerve.

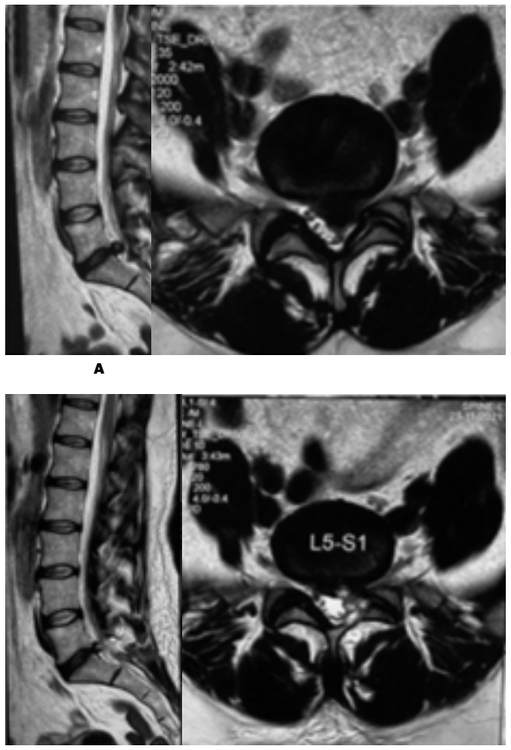
The biportal endoscopic surgical technique allows to avoid damage of normal structures and nerves, and to perform decompression on the contralateral side with free manipulation using standard surgical instruments

The wide field of view and the angle that can be varied during this procedure contribute to a more comfortable management of foraminal stenosis. Good anatomical orientation and visualization of the foraminal structures is important for the novice. Aiming at the superior articular process is one of the main keys to orientation at the beginning. This area is a safe zone. With sufficient removal of the bony fragments of the superior articular process using a drill or osteotome, a satisfactory decompression can be made. In contrast to other endoscopic techniques, the advantage of this surgical technique is the protection of the nerve during manipulations around the nerve structures with the use of a retractor by the assistant.

The biportal endoscopic surgical technique allows to avoid damage of normal structures and nerves, and to perform decompression on the contralateral side with free manipulation using standard surgical instruments.

Case No. 1. Patient G., 41 years old. Diagnosis: osteochondrosis of the lumbosacral spine. Sequestrated herniation of the L5-S1 intervertebral disc with discradicular conflict on the left side (Fig. 1A). Sensomotor radiculopathy of L5-S1 on the left. Conservative medication treatment with no pronounced positive effect. For 10 days before hospitalization, the patient noted increasing weakness in the left lower extremity. On examining the patient's neurological status: no Achilles reflex on the left side, on the right side — healthy. Paresis: weakness of the left big toe up to 3 points. Tension syndrome: none. Vertebral syndrome: flattened lumbar lordosis. Pain on palpation of paravertebral points: at the lumbar level. Sensation: hypalgesia on the dorsum and sole of the left foot.

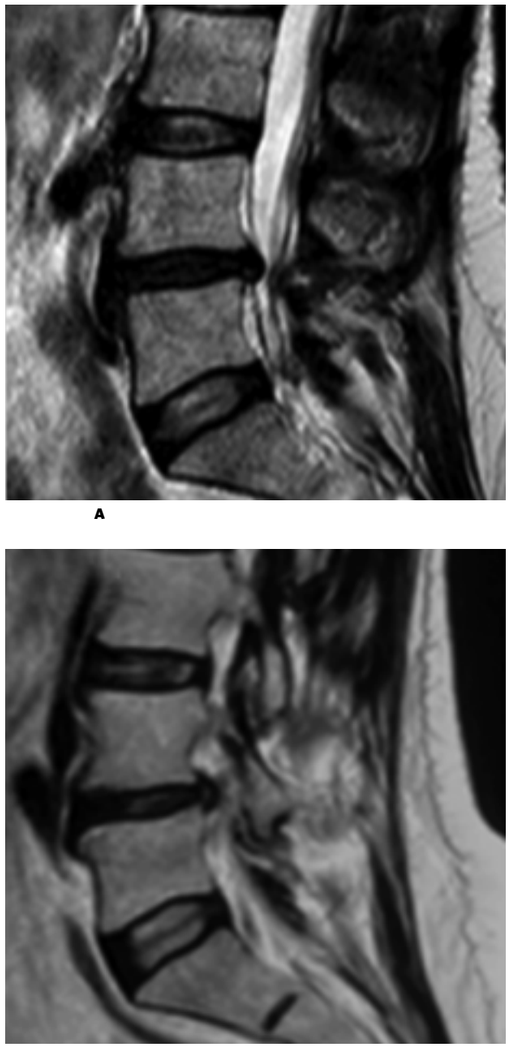
The surgery was performed: partial medial resection of the L5-S1 facet joint on the left, flavectomy, nucleotomy, removal of the L5-S1 intervertebral disc herniation using a biportal endoscopic technique, and radiculolysis of the L5 left. On MRI, the L5 radicle on the left was freed (Fig. 1B). The duration of surgery was 1 hour and 40 minutes. After the operation, neurological symptoms regressed and



A

B

Fig. 1. Magnetic resonance imaging of the lumbar spine: A — before surgery, sequestered herniated intervertebral disc L5-S1 with discradicular conflict on the left; B — after surgery, postoperative defect in the left side of the L5 vertebral arch and postoperative changes of intervertebral disc L5-S1 in the left paramedial segment are revealed, sequester removed, L5 spinal root on the left is freed



A

B

Fig. 2. Magnetic resonance imaging of the lumbar spine: A — foraminal stenosis at the level of L4-L5; B — postoperative defect in the left side of the L4 vertebral arch is revealed, narrowing is eliminated

pain syndrome decreased. The patient was discharged from the unit on the 2nd day after the operation.

Case No. 2. Patient R., 53 years old. Diagnosis: osteochondrosis of the lumbar spine. Combined stenosis of the L4-L5 spinal canal. Vertebrogenic intermittent claudication, chronic pain syndrome.

The patient was admitted with complaints of pain in the lumbar spine (up to 8 points on the VAS) with irradiation to the lower extremities, after walking 500 m the weakness and numbness in the thighs was increasing, the patient had to rest. MRI showed combined stenosis of the L4-L5 spinal canal with compression of the neural structures at this level (Fig. 2A)

Biportal endoscopic decompression of the spinal canal was performed: partial hemilaminectomy L4-L5 on the left side, endoscopic bilateral "over-the-top" decompression of the spinal canal at the level of L4-L5. The surgery duration was 1 hour and 35 minutes. The patient was verticalized on the 1st day after surgery, had complaints of minor pain in the area of surgical intervention, and was discharged on the 2nd day.

Discussion. Degenerative diseases are one of the most frequent causes of spinal surgery in elderly patients [12]. There are two main options for surgical treatment of lumbar stenosis: decompression without spinal fusion and decompression with spinal fusion [17-19]. Interbody fusion in the treatment of foraminal stenosis in the lumbar spine is recommended as the "gold standard", although dynamic fixation methods have also been proposed [20]. However, it has also revealed some limitations, such as incomplete decompression, postoperative sensory impairment, and postoperative instability due to excessive bone resection, which is known to lead to adverse clinical outcomes and ultimately requires spinal fusion surgery.

In order to achieve successful clinical outcomes, the technique of microscopic foraminal decompression with preservation of the facet joint and the use of paraspinal access was introduced [18]. Other minimally invasive approaches have also been developed [21, 22]. Some authors have reported the use of a technique known as percutaneous endoscopic foraminoplasty [16]. Previous studies of endoscopic foraminoplasty have shown promising surgical results not only in the short-term, but also in long-term follow-up evaluations. However, it is technically difficult and, in addition, this method has the same disadvantages as open surgery, such as incomplete decompression and postoperative instability due to the damage of the facet joint [23].

Endoscopic surgery of the spine has become widespread over the past decade due to the development of surgical techniques and the appearance of special instruments. This approach has many significant advantages over open techniques, in particular, fewer complications and comparable results in the surgical

Biportal endoscopic surgery for degenerative diseases of the lumbar spine is a minimally invasive, innovative, effective, and safe technique

treatment of disc herniations and spinal canal stenosis [24, 2]. However, there are certain disadvantages: limited field of view, small working space, complicated training trajectory, radiation exposure, costs, deterioration of treatment results, and complications. Nevertheless, we perform biportal endoscopy of the spine in its degenerative diseases because the method allows to achieve clear and magnified images, to perform direct decompression, has minimal invasiveness, and it can be used in almost all degenerative diseases of the spine. The main advantages are: 2 small incisions (about 7 mm) for the ports, minimal damage to muscles and ligaments, minimal blood loss, low risk of infection, minimal scarring and adhesions, excellent visibility, minimal hospitalization time. Minimal invasiveness is achieved through muscle preservation and minimal blood loss, resulting in low postoperative pain syndrome and a rapid return to normal life. Importantly, the biportal technique is economically more advantageous than the single-portal one, since it does not require special expensive instruments. A standard arthroscopic rack, which is usually available in almost any trauma and orthopedic hospital, with a 4-mm arthroscope and 0o or 30o optics is used [25]. Bipolar radiofrequency ablator is used for hemostasis, arthroscopic shaver and drill for bone and soft tissue dissection and removal, and standard instruments for spinal surgery used for open access. In addition, it is impossible to fully view the lesion site and adjacent nerve structures in a narrow corridor using a single-portal system [26]. That is why we choose the biportal system, which provides a wide viewing angle and free access of surgical instruments, limited by the single-portal approach. In contrast to the single-portal system, we can manipulate in the area of the pathological locus, protecting the nerve structures with a nerve root retractor when the yellow ligament, which protects the nerve structures, is removed. Considering the closeness of the arthroscope optics to the nerve structures compared to the microscope optics, the arthroscope provides better visualization of the nerve structures. Similar to the microscope, the arthroscope can also visualize the contents of the spinal canal from the opposite side, as described in Clinical Case No. 2 [13].

The incidence of various complications during biportal endoscopy of the spine is under 6%. The main ones are spinal root and dura mater damage as well as insufficient decompression. Poor visualization due to poor bleeding control and inadequate irrigation can lead to such problems, especially in novice surgeons [27]. However, the training trajectory is relatively short, and the complication rate in the early period of training is approximately 10.3% [28].

Conclusion. Biportal endoscopic surgery for degenerative diseases of the lumbar spine is a minimally invasive, innovative, effective, and safe technique. This approach allows direct decompression of nerve structures under clear visualization while keeping soft tissue and facet joint damage to a minimum, which helps avoid instrumental fixation. In addition, the training trajectory for this technique is less "steep" than for other endoscopic decompression techniques.

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