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Original article

Clinical and Functional Results of Transcatheter Arterial Embolization as a Treatment for Knee Osteoarthritis

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Running title: Arterial Embolization in Knee Osteoarthritis

Abstract

Objectives: To evaluate the effectiveness of our first experience in employing transcathether arterial embolization (TAE) of popliteal artery branches in patients with knee osteoarthritis (OA). **Materials and methods:** The research included 80 people with knee OA grades 1-2, resistant to standard conservative treatment and without indications for surgical intervention. The patients were divided into 2 groups of 40 people each; in group 1, intra-articular injection of sodium hyaluronate (synovial fluid prosthesis) was chosen as minimally invasive therapy; in group 2, TAE of popliteal artery branches was performed. Clinical and functional characteristics of joints were assessed using WOMAC and Lysholm scales at baseline and 3 months after intervention. **Results:** Before surgery, in both groups 1 and 2, high levels of WOMAC scale (150 [138-184] and 162 [140-190] points, respectively) and low levels of Lysholm scale (42 [35-54] and

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40 [38- 60] points, respectively) were recorded. At 3 months after treatment, patients of both groups demonstrated significant improvement in clinical and functional results in the form of decrease in WOMAC scale to 94 [84-120] for group 1, p<0.001; and 52 [40-79] points for group 2, p< 0.001. According to Lysholm scale, satisfactory results were obtained in group 1 (68 [60-85] points, p = 0.001) and good results in group 2 (91 [85-95] points, p < 0.001). On comparison of both groups, patients with TAE achieved lower values of WOMAC (p = 0.023) and higher values of Lysholm scale (p = 0.06). No complications were recorded in both groups. **Conclusion:** TAE of popliteal artery branches is an effective minimally invasive intervention that significantly reduces severity of pain and improves the function of knee joints. This method requires more studies with larger number of patients, development of selection criteria in order to increase accessibility in practical healthcare.

Keywords: osteoarthritis, knee joint, transcatheter arterial embolization, WOMAC, pain.

1. Introduction

Rheumatic diseases are a heterogeneous group of chronic conditions that are characterized by development of severe concomitant conditions in patients. These ailments cause a tremendous negative impact on the modern society as they act as both physiological and psychological burden on patients and as economic burden on the society. Osteoarthritis (OA) is the most common joint pathology worldwide which is accompanied by chronic pain, disability, and showcases a prediction of further increase in incidence.

In 2020, approximately 595 million patients with OA were identified, corresponding to 7.6% of the world population, this amounted to a 132.2% increase in prevalence compared to 1990 [1]. The incidence rate of OA continues to rise, largely due to the expansion of the “elderly” population and the absence of effective treatment. By 2050 the prevalence of knee OA is projected to increase by 74.9%, hand OA - by 48.6%, hip OA- by 78 .6% [1]. In addition to the annual dynamic increase in incidence, a significant rise of this pathology has been noted among the working demographics [2], which is of great medical and social importance for the state.

Management of OA involves the use of a range of methods. According to modern recommendations, treatment should be carried out using a

complex of pharmacological and non-pharmacological methods, taking into account risk factors (obesity, mechanical factors, physical activity), general factors (age, comorbidity, polypharmacy), the level of intensity of pain and functional impairment, the presence or absence of signs of inflammation, localization and severity of structural changes [3, 4]. Despite much research, there is no cure for OA and a distinct lack of disease-modifying drugs persist against the background of reliance on abundant symptomatic pharmacological agents. Another pressing problem of OA is its clinical and pathogenetic variability and pronounced polymorbidity, which in many cases neutralizes the effectiveness of a number of therapeutic strategies [5].

The presence of multiple somatic diseases in an OA patient which are managed by complex combinations of medications creates the need for a proper assessment of the expected benefits and possible risks of a particular treatment method. The chosen intervention should be the safest and most effective one.

One of the promising methods for managing OA is transcatheter arterial embolization (TAE) of popliteal artery branches. It is a new, minimally invasive technique that is used to relieve pain in knee OA and is based on the observation that inflammation causes abnormal neovascularization and sensory nerve fiber growth [6]. It has been identified that pathogenetically excessive angiogenesis in OA is caused by inflammation that aggravates to more inflammation and stimulates an increase in the number of pain receptors, thereby causing persistent pain syndrome [7, 8, 9]. Neoangiogenesis can stimulate the growth of osteophytes that results in pain. Furthermore, this process in the synovium can cause disruption of the homeostasis of hyaline cartilage and hypoxia of chondrocytes [10].

As a rule, the area of pathological vascularization is located in the projection of the medial part of the knee joint and is supplied by a network of branches of the popliteal artery. The TAE method involves catheterization and angiography of the femoral artery, popliteal artery and its branches, followed by embolization of the hypervascular area.

There is relatively little scientific data regarding TAE of the branches of the popliteal artery, and their results are often contradictory. But this method has shown effectiveness in small samples of patients with knee OA grades 2-2 [11, 12, 13]. According to the available data, improvement in pain and joint function is achieved in 86.3% of patients after 6 months, in 79.8% after 3 years [6] and the technique is well tolerated by patients over 50-60 years of age [14]. This intervention demonstrates significantly less pronounced

synovitis after a year, compared with the baseline on verification by MRI using the WORMS scale [15].

It is notable that this method was found to be insufficiently effective in late stage OA [16], but the early stages of the disease with resistance to standard therapy is a considerable indication for this method [13]. Review works presented in literature indicate the success of this technique, especially in cases when conservative therapy was ineffective or contraindications to surgical treatment existed [17].

Unfortunately, the small sample of patients for TAE of popliteal artery does not allow us to determine the current place of this method for employment in management of knee OA. In some patients, insufficient effectiveness is observed, thus further research is necessary to introduce this treatment method into everyday clinical practice.

The aim of research was to evaluate the effectiveness of our first experience in employing the use of TAE of popliteal artery branches in patients with knee OA.

2. Materials and Methods

The research was carried across a time-frame of one year at Orenburg Regional Clinical Hospital named after V.I. Voinov, in the departments of Traumatology and Orthopedics and Endovascular Surgery. Analysis of treatment results of 80 patients with 1-2 grades knee OA aged from 45 to 60 years who underwent minimally invasive therapy due to ineffectiveness of prior pharmacological management were analyzed. All patients received standard pharmacological therapy as prescribed by the National Clinical Recommendations for OA (2021), including NSAIDs, SYSADOA, as well as non-pharmacological treatment in the form of physical therapy and orthotics for a duration of 3-6 months.

The patients were divided into 2 groups of 40 people each; in the first group, intra-articular injection of sodium hyaluronate (synovial fluid prosthesis) was performed and in the second group TAE was done.

Before undergoing procedures, all patients underwent evaluations with collection of complaints and medical history, inspection, and assessment of amplitude of active and passive movements in the knee joints. The diagnosis of knee OA was made taking into account the criteria of Altman R. (1991), and verification of the grading radiographically according to Kellgren-Lawrence criteria. All participating patients of this study provided their

informed voluntary consent. Patients in both groups had no indications for surgical treatment of OA against the background of ineffectiveness or insufficient effectiveness of previous pharmacological treatment. All patients included in the study underwent contrast-enhanced MRI of the knee joint. Particular attention was paid to the presence of abnormal vascular network, indicating active neoangiogenesis. If this was present, patients were candidates for inclusion in the second group, whereas the main exclusion criterion was the absence of a hypervascular network in the knee joint due to the perceived risk of non-target embolization. Patients with allergies or other contraindications to intra-articular administration of hyaluronic acid preparations were excluded in the first group.

All patients underwent a clinical and functional examination using the WOMAC and Lysholm questionnaires. The WOMAC scale was a questionnaire of 24 questions, for each of which the patient selected a number of points from 0 to 10, similar to the visual analogue scale, where 0 points stood for the complete absence of a sign, and 10 points indicated maximum severity. A higher score corresponded to a worse result. The assessment of the knee joint function according to the Lysholm scale was also carried out in points, where the maximum sum was equal to 100 points and corresponded to a healthy knee joint, and dysfunction was determined by a decrease in the total score. The Lysholm score points indicated: less than 64 points – unsatisfactory, 65–83 – satisfactory, 84–94 – good, 95–100 – excellent.

The TAE procedure was performed as follows. Under local anesthesia, arteriography of the lower third of the superficial femoral artery and popliteal artery, including 3D reconstruction, was performed using antegrade transfemoral access (Figure 1). During evaluation of the angiogram, areas of increased vascularization were identified, if any, and the architecture of the arteries was analyzed, with special emphasis on the medial aspect of the knee joint. To identify vessels subject to embolization, as well as to construct the trajectory of target vessels, a specialized Embolization Guidance program (Siemens) was used. This software is for advanced embolization planning and guidance. Knowing the location of the lesion and vessels is essential for complete embolization of pathological process. This program simplifies catheter navigation for any embolization procedure, regardless of the body region. The software's 3D reconstruction of the arterial tree was used to facilitate cannulation of the target branch, including selection of the optimal projection and superimposition of the live image onto the color-coded 3D reconstruction. In most cases, the target artery for embolization was medial genicular artery. The software allowed

for selection of the optimal projection for catheterization of target branch ostium and superimposition of the live image on a color-coded 3D reconstruction to reduce the use of contrast agent. Catheterization of target branch was carried out with a Berenstein catheter or one of the diagnostic coronary catheters, depending on the angle of origin of the artery, after which a microcatheter was inserted through the coronary guidewire. Through a microcatheter, a suspension of microspheres with a diameter of 150-250 μm, diluted in physiological solution with the addition of a contrast agent in a 1:1 ratio, was slowly introduced. To prevent off-target embolization, the authors followed the principles: precise mapping using 3D navigation, neuromicrocatheters, which achieved superselective catheterization of the target artery, and calibrated (the smallest) polyvinyl alcohol particles for embolization. After contrast stasis appeared, control angiography was performed, which confirmed occlusion of the embolized artery (Figure 2). The operation was completed by applying a pressure bandage.

Figure 1. Patient A., 42 years old, knee osteoarthritis grade 2. A: Arteriography of superficial femoral, popliteal artery and its branches. B: 3D reconstruction of



vessels based on data of angiography.

Evaluation of treatment results was done 3 months after the procedure in a consultation where the survey was repeated, complaints, the number of complications, the amplitude of active and passive movements in the knee joints were assessed, the functional result was re-evaluated using the WOMAC and Lysholm scores. The obtained data was compiled into an Excel table and a statistical analysis was then carried out using the Statistica 10.0 program. Quantitative indicators were recorded as median, upper and

lower quartiles (Me [Q1-Q2]), the differences between the groups were determined using Mann-Whitney U test, the significance level, p was 0.05.



Figure 2. Patient A., 42 years old, knee osteoarthritis grade 2. A: Arteriography before TAE showing hypervascular network of the medial genicular artery. B: Arteriography after TAE showing no contrast spread distal to the embolized target artery

3. Results

First group of patients included 35 (87.5%) women, 5 (12.5%) men, the average age was 50 [46-56] years. In the second group of patients there were 32 (80%) women, 8 (20%) men, the average age was 53 [47-58] years. Both groups were comparable in terms of gender and age characteristics.

Assessment of effectiveness of treatment methods revealed the persistence of pain and functional limitations 3 months after intervention in 6 (15%) cases in group 1 and in 9 (22%) cases in group 2. No complications in either group were recorded.

The results of clinical and functional studies of patients in both groups are presented in Tables 1 and 2.

Table 1. Results of a clinical and functional examination of knee joints in patients with knee OA by WOMAC scale.

Group	Sum of WOMAC points before treatment	Sum of WOMAC scores 3 months after treatment	Statistical significance, p-value
Group 1 (synovial fluid prosthesis)	150 [138-184]	94 [84-120]	<0.001
Group 2 (transcatheter arterial embolization)	162 [140-190]	52 [40-79]	<0.001

Statistical significance, p-value	0.840	0.023	

According to the results in Table 1, before the employment of minimally invasive intervention, significantly high WOMAC scale scores were recorded in both groups of patients, indicating considerable clinical and functional disorders of the knee joints. No substantial differences in this indicator existed prior to the treatment. 3 months later, the patients showed noteworthy improvement, characterized by a significant decrease in WOMAC scores in both groups but the patients in the TAE group achieved significantly lower levels of this scale.

Table 2. Results of a clinical and functional examination of knee joints in patients with knee OA by Lysholm scale

Group	Sum of Lysholm points before treatment	Sum of Lysholm scores 3 months after treatment	Statistical significance, p-value
Group 1 (synovial fluid prosthesis)	42 [35-54]	68 [60-85]	0.001
Group 2 (transcatheter arterial embolization)	40 [38-60]	91 [85-95]	<0.001
Statistical significance, p-value	0.94	0.06	

On pre-intervention analysis of Lysholm scale results of both groups, disappointing data was obtained (less than 64 points), which indicated a pronounced impairment of knee joint functioning. The results of both groups was comparable with no significant differences. 3 months after treatment, in both groups, similar to the WOMAC scale, a significant improvement in the Lysholm index was obtained, and as per the scale, patients who received a synovial fluid prosthesis showed satisfactory results, and patients after TAE indicated good results.

4. Discussion

The first clinical experience of application of TAE of popliteal artery branches in our clinic indicated the method to be an effective minimally invasive therapeutic option, the functional result of which is superior to traditional conservative methods of treating knee OA grades 1-2. These results are comparable to previously published similar studies [11, 15, 17], majority of which had larger samples and thus, reduced risk of statistical error. Decreased pain and no further requirement of NSAIDs is a favorable outcome for prevention of complications in patients with diseases of the gastrointestinal tract and cardiovascular system. Furthermore, there are reduced risks of postoperative complications.

However, the widespread use of this technique presents itself with certain limitations which are primarily associated with little knowledge of the long-term results of its application. Our study included a 3-month follow-up period after the procedure to analyze early complications. However, a 90-day window is insufficient to determine the durability of TAE or the potential late-onset complications like avascular necrosis. Therefore, the results of short-term observation cannot be extrapolated to the efficacy and safety of the method as a whole, and it is necessary to continue monitoring patients for a longer period. It should be noted that the absence of a control group without any interventions limits the internal validity of the reported success rates, which also argues for the need to continue monitoring patients.

No data is available on the use of this technique in patients with concomitant cardiovascular, endocrine and neurological diseases. Theoretically, these pathologies may increase the risk of complications such as ischemic necrosis of the skin and avascular necrosis of the condyles of femur and tibia. Furthermore, it is noteworthy that the number of patients in whom the TAE intervention was ineffective (lack of positive dynamics) with TAE were slightly higher on comparison with the synovial fluid prosthesis group. We analyzed cases of insufficient TAE efficacy. It can be concluded that this is independent of the patient's gender or body mass index, although there is a tendency for unsuccessful results in older patients. Angiographic characteristics also do not provide convincing data, so it is necessary to conduct further search for causes and verification of “suitable” patients, development of clearer indications for this method.

Moreover, it is essential to continue researching the variants of the anatomical structure of the pathological vascular networks that develop in OA of knee joint as it would increase the effectiveness of the method by detailing the causative branches of the popliteal arteries which would be accurately embolized and would lower the risk of development of ischemic complications from surrounding tissues. Above all, insufficient data is available regarding the comparative effectiveness of TAE in OA patients based on grading and age-sex correlation of treatment results. However, we do not recommend TAE in patients with OA grades 3-4, as the procedure is ineffective in advanced stages, according to the literature [16]. It is logical to assume that the significant changes in joint structures observed in late stages, involving the articular bone, subchondral cartilage, and ligamentous apparatus of the knee, will not allow for significant positive clinical results when addressing the vascular factor alone.

5. Conclusions

TAE of popliteal artery branches is an effective minimally invasive intervention that significantly reduces the severity of pain in patients and improves the functional parameters of knee joint. This method has low risk of complications and can be used to alleviate pain in knee OA grades 1-2. On the other hand, this method requires further research, expansion of patient samples, development of a selection criteria in order to increase accessibility for practical healthcare.

Author Contributions

Conceptualization: A.A., V.V.; Methodology: V.V.; Formal analysis: A.G., T.V.; Investigation: V.I., A.Z., K.M.; Writing – original draft: K.K., K.M.; Writing – review & editing: all authors.

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Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Orenburg State Medical University (№ 357, 02.05.2025).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data presented in this study are available on reasonable request from the corresponding author.

Conflicts of Interest

The authors declare no conflict of interest.

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