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Reverse shoulder arthroplasty in cases of glenoid defects using primary-revision metaglene

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ABSTRACT

BACKGROUND: Reverse shoulder arthroplasty is one of the surgical treatment methods of the shoulder joint injuries and diseases accompanied by pronounced changes in the anatomy of the articular structures. Considering the positive aspects of reverse shoulder arthroplasty, the indications for this operation are expanding over time. However, during this operation, errors are possible that lead to early dislocation of the endoprosthesis, compression of the metaglene to the scapula, screw instability and migration of the scapular component. Given the lack of a generally recognized clear algorithm of actions in these complex cases, the problem of reversible shoulder arthroplasty in case of defects in the articular surface of the scapula are relevant.

AIM: To develop and evaluate the effectiveness of the method of compensating for the lack of bone tissue of the scapula in the reverse shoulder arthroplasty

MATERIALS AND METHODS: In the Department of Adult Orthopaedics of the N.N. Priorov National Research Medical Center, reverse shoulder arthroplasty was performed in patients with scapular bone mass deficiency, who needed to fill in both marginal defects for the installation of metaglene with the correct angle of inclination, and the replacement of extensive defects with the necessary level of glenosphere lateralization.

RESULTS: Follow-up of patients who underwent glenoid remodeling using bone autoplasty and subsequent shoulder reverse artroplasty within a period of 6 to 24 months. Remodeling and osseointegration of the grafts were determined, without signs of metaglene instability by the end of the 3rd month after the operation. The complex of rehabilitation measures and the time of recovery of movements in the operated joint did not differ from those of conventional reverse arthroplasty.

CONCLUSION: Given the high efficiency of the proposed algorithm, the method used to compensate for the lack of bone tissue of the scapula in shoulder reverse arthroplasty can be recommended for implementation in a wide clinical practice.

Keywords: reverse arthroplasty; shoulder arthroplasty; glenoid; bone grafting.

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INTRODUCTION

Reverse arthroplasty is one of the methods of surgical treatment of injuries and diseases of the shoulder joint, accompanied by pronounced anatomical changes in articular structures [1]. Given the positive aspects of reverse arthroplasty such as displacement of the center of rotation of the joint and improvement of the tension and tone of the deltoid muscle, the indications of this surgery expand over time [2]. In the literature, traumatologists encounter deficits in the bone mass of the articular process of the scapula in 38% of the cases of reverse shoulder arthroplasty with deforming or post-traumatic osteoarthritis (Fig. 1) [3, 4]. These subtotal or total defects of the glenoid are particularly problematic for the correct installation of the scapular components of the endoprosthesis because of the difficulties of the intraoperative differentiation of the true and false planes of the articular surface.

According to the literature, special guiding instruments have been created for such cases, which are used to install the metaglene in the correct position in relation to the scapula neck [5]. In these cases, the medialization of the glenosphere is unacceptable, and it is also undesirable to conduct the metaglene stem and fixing screws through the defect area outside the bone tissue. This mistake leads to early dislocation of the endoprosthesis. The disrupted compression of the metaglene to the scapula, screw instability, and migration of the scapular component are also possible.

Methods for leveling the deformity of the scapular articular surface using bone autoplasty from the resected shoulder head or alloplasty use augments and modify the scapular components of the endoprosthesis [6]. Many authors indicate that spongious autografts are the most optimal osteoplastic material, since spongeous bone has a high potential for synostosis and, accordingly, more pronounced osteogenic, osteoinductive, and osteoconductive properties [7, 8]. Given the lack of a generally recognized clear algorithm of actions in these complex cases, the problem of reverse shoulder arthroplasty in case of defects in the articular surface of the scapula can be considered relevant.

MATERIALS AND METHODS

In the Department of Orthopedics for Adults of the Priorov National Medical Research Center of Traumatology and Orthopedics, a reverse shoulder arthroplasty was performed in six patients with scapula bone mass deficiency, who needed replacement of both marginal (n = 4) and extensive bone defects (n = 2) to install the metaglene with correct inclination angle and to create the required level of glenosphere lateralization.

Preoperatively, clinical, radiological, and instrumental examinations of the patient were performed. Pain syndrome, joint range of motion, and functional state of the deltoid muscle were assessed. Radiographs of the shoulder joint in two projections were obtained, as well as data from multispiral computed tomography (CT) of the shoulder joint with visualization of the scapular articular process and three-dimensional modeling. This was based on CT in which the volume of the proposed reconstruction of the articular process of the scapula, which could be in several versions, was assessed.

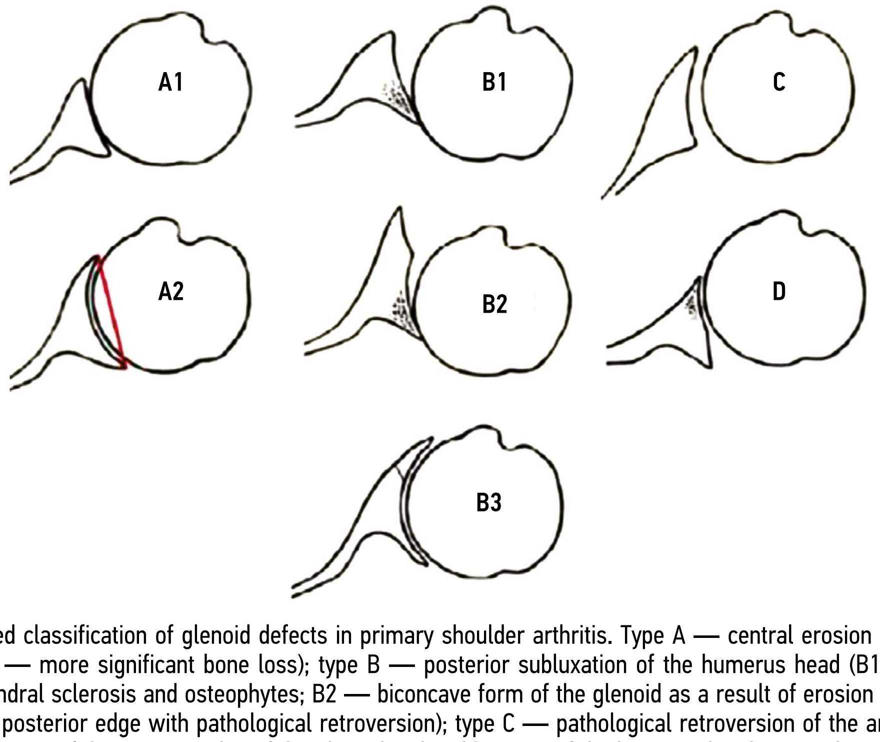

Fig. 1. Walch modified classification of glenoid defects in primary shoulder arthritis. Type A — central erosion of the glenoid (A1 — minimal erosion,; A2 — more significant bone loss); type B — posterior subluxation of the humerus head (B1 — narrowing of the articular gap, subchondral sclerosis and osteophytes; B2 — biconcave form of the glenoid as a result of erosion of the posterior edge; B3 — erosion of the posterior edge with pathological retroversion); type C — pathological retroversion of the articular surface of the scapula; type D — erosion of the anterior edge of the glenoid with subluxation of the humerus head anteriorly

In case of the marginal defects of the articular surface of the scapula without medialization of its entire surface, bone autoplasty and graft fixation were performed, followed by endoprosthetics. Plastic repair of glenoid marginal defects was performed as follows. After surgical access to the shoulder joint, skeletonization of the glenoid articular surface was performed, and scar tissues and articular cartilage were removed. In addition to preoperative planning based on CT with three-dimensional modeling, visual, manual, and instrumental assessments of the defect parameters and the amount of bone loss in the articular surface of the scapula were performed. Then, an incision was made on the skin and subcutaneous tissue in the projection of the iliac crest. The muscle fibers were bluntly separated, the ilium surface was visualized, and the bone autograft of the required size was collected using an osteotome. Hemostasis with a layer-by-layer wound closure was performed. The graft was modeled with special instruments. After reconstruction of the graft shape corresponding to the defect, the graft was implanted into the defect area. Osteosynthesis of the graft was performed with cannulated metal or bioresorbable screws. The metaglene was installed, taking into account the inclination angle of the formed articular process of the scapula and patient's biomechanical data (such as the presence of thoracic kyphosis). Compression and tight fit of the surfaces of all elements of the scapula–graft–metaglene system were achieved, without gaps and empty spaces. The metaglene was then fixed with screws; it was essential to place screws of the required length into the scapular body to ensure autograft compression, stability, reconstruction, and subsequent consolidation with the scapular bone tissue. Even in the absence of pronounced medialization of the metaglene and replacement of minor defects, it is advisable to choose revision metaglene with an elongated stem for a more stable fixation (Fig. 2). Fundamentally, the long stem of the metaglene should enter the body of the scapula.

Autoplasty with a graft of a significant size is required if there is a massive deficit of bone mass of the glenoid and medialization of the bone site for metaglene implantation. In this case, the elongated metaglene stem was brought into the scapula through the graft center. After surgical access to the shoulder joint, the scar tissue was removed, and the articular surface of the scapula was treated with a cutter. According to the preoperative planning and intraoperative presentation, the graft thickness was calculated for the required lateralization of the articular surface of the scapula. An incision was made on the skin and subcutaneous tissue in the projection of the iliac crest. The muscle fibers were bluntly separated, the surface of the ilium was visualized, and the bone autograft was collected with an osteotome. Hemostasis and wound closure were performed. The graft was designed, and autoplasty was performed using a graft of considerable size to lateralize the metaglene. Moreover, the graft was installed along

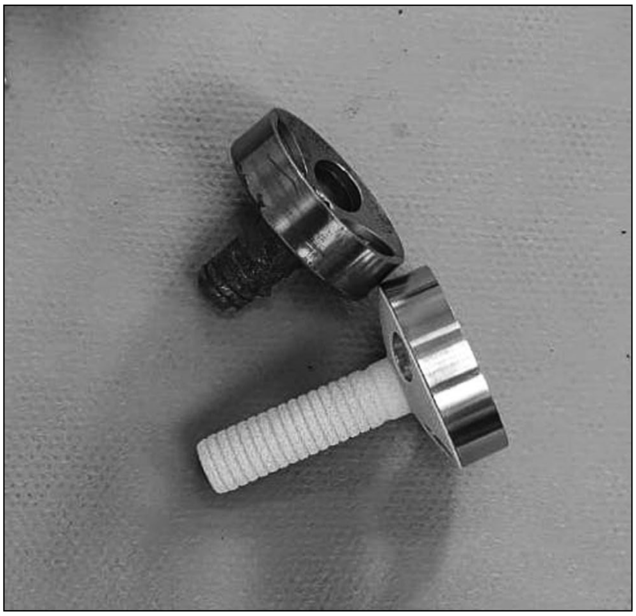

Fig. 2. Standard metaglene and revision metaglene with a long peg

the guide wire, along which the canal of the metaglene stem was drilled through the graft. The metaglene was placed through the autograft center into the scapula neck and body, considering the inclination angle of the articular process and patient's biomechanical data. Compression and tight fit of the surfaces of all elements of the scapula–graft–metaglene system were achieved in relation to each other on the elongated metaglene stem without gaps and empty spaces. The metaglene was then fixed with screws, and it was essential to pass the screws of the required length through the bone graft into the body of the scapula to ensure its compression, stability, remodeling, and subsequent consolidation with bone tissue.

Clinical case

Patient S, 75 years old, applied to the department of orthopedics for adults of the Priorov National Medical Research Center of Traumatology and Orthopedics with complaints of pain and dysfunction of the right shoulder joint. Clinically, severe limitation of the range of motion, pain syndrome, and moderate hypotrophy of the deltoid muscle were noted (Fig. 3).

The patient had a history of gunshot injury in the right shoulder joint more than 15 years ago and had repeated reconstructive surgery on the shoulder joint. X-ray imaging and CT revealed post-traumatic arthrosis of the right shoulder joint with pronounced "wear" and medialization of the glenoid and a defect in the proximal humerus (Fig. 4).

Reverse shoulder arthroplasty was performed with replacement of a significant bone defect in the glenoid using a graft from the iliac crest, according to the method described above (Figs. 5 and 6).

All stages of surgery must take place under the control of an electro-optical converter (Fig. 7). Postoperatively, an

Fig. 3. Appearance of patient S., hypotrophy of the deltoid muscle, limited range of motion in the shoulder joint.

Fig. 4. Patient S., 75 years old. X-ray picture

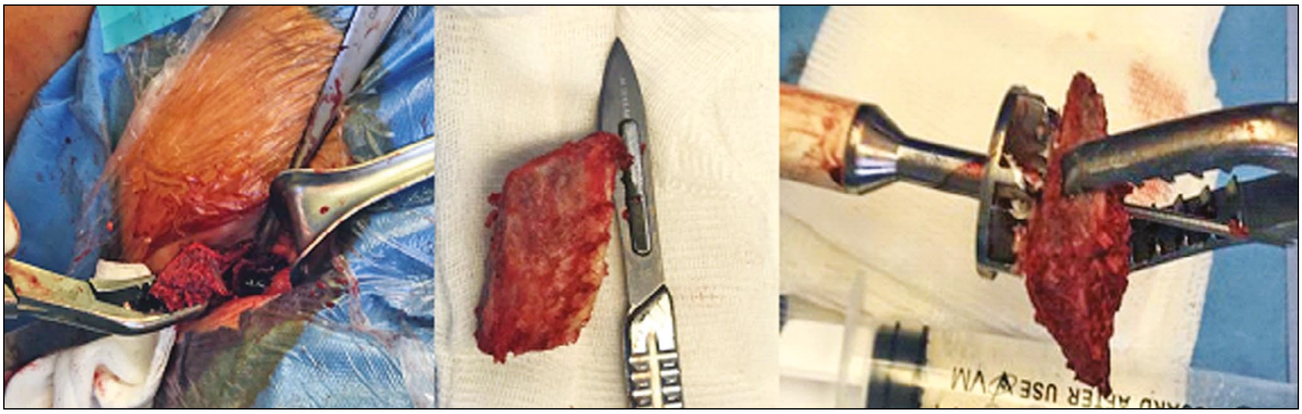

Fig. 5. Autograft sampling, modeling, and processing

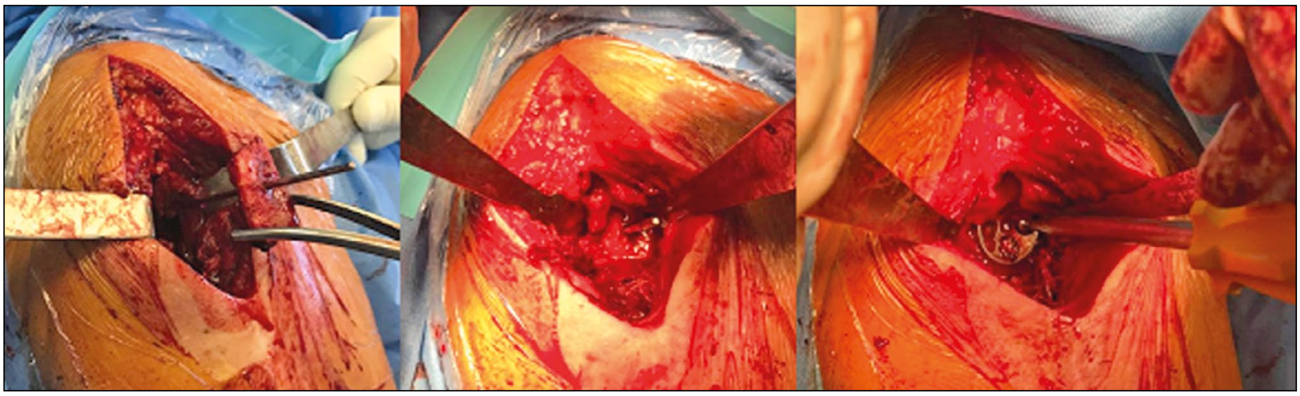

Fig. 6. Needle graft implantation, metaglene insertion

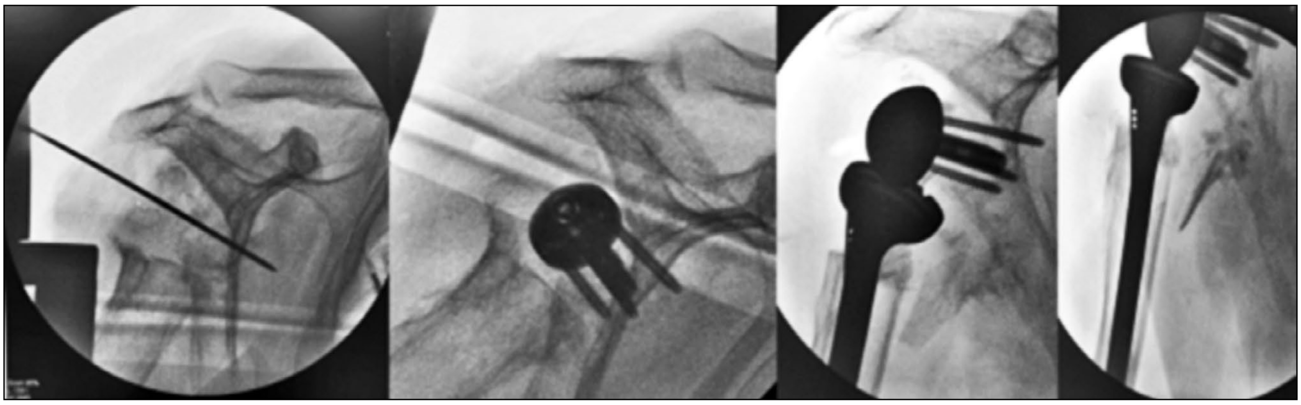

Fig. 7. Step-by-step intraoperative X-ray control

external immobilization of the operated limb with an orthosis, removable for rehabilitation measures, was performed. The patient followed a rehabilitation course, which included mechanotherapy and electrical stimulation of the deltoid muscle in the early stages after surgery.

RESULTS

Patients who underwent bone autoplasty of the glenoid and subsequent reverse arthroplasty were monitored in 6–24 months. Good clinical, radiological, and functional results were obtained. The surgical wounds healed by primary intention, and no postoperative hematomas or proinflammatory complications were recorded. The main criterion was the absence of dislocation of the endoprosthesis in all six patients during the follow-up period. According to CT data, remodeling and osseointegration of the grafts were determined, without signs of instability of the metaglene and screws fixing the graft by the end of month 3 postoperatively. The rehabilitation measures and timing of movement recovery in the operated joint did not differ from those of conventional (without bone grafting) reverse arthroplasty.

DISCUSSION

When the revision scapular component of the reverse shoulder joint endoprosthesis is installed on the medialized articular surface of the scapula, the glenosphere is medialized and the center of the joint rotation changes. This leads to complications associated with impaired centering of the graft stem in relation to the glenosphere and the absence of the necessary tension and tone of the deltoid muscle. These impairments of biomechanics during reverse arthroplasty result in dislocations of the shoulder component.

In our practice, we choose the ridge of the iliac wing as the graft collection area since the cortical–spongious graft possesses the necessary mechanical properties and is optimal in the reparative regeneration and restoration of bone mass. Replacement of significant defects, medializing the glenoid, made it possible to perform stable fixation of the cortical–spongious graft on the metaglene stem with sufficient compression using screws. Under similar conditions, a spongious graft from a resected humerus head has a more pliable structure and does not require the necessary mechanical strength for the glenoid lateralization. Moreover, the head can often be completely absent in case of hypovascular and degenerative dystrophic changes. In some conditions and post-traumatic changes in the proximal humerus, it is also not possible to collect bone tissues from this zone.

The development of a clear algorithm of actions depending on the shape and volume of the defect is important in solving the problem of glenoid bone mass deficiency during reconstructive interventions and shoulder arthroplasty. In our experience, in most cases, the metaglene instability and dislocations of the endoprosthesis were caused by the incorrect installation of the scapular component with an improper angle of installation and offset of the glenosphere. Given the high efficiency of the proposed algorithm, the method used to compensate for the deficit of the scapula bone tissue during reverse shoulder arthroplasty can be implemented in broad clinical practice.

ADDITIONAL INFO

Author contribution. Thereby, all authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work.

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Evaluation of the effectiveness of the use of low-traumatic surgical access in the reverse shoulder arthroplasty

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ABSTRACT

BACKGROUND: The number of reversible shoulder joint endoprostheses installed in the world at the present stage is several times greater than the number of hemiarthroplasty performed. Nevertheless shoulder arthroplasty is considered a traumatic operation and can be accompanied by a number of complications, both from the side of implants and due to the traumatic nature of the surgical technique. During surgical interventions on the shoulder joint with a wide dissection of the skin and subcutaneous tissue, iatrogenic damage to structures such as the axillary nerve, posterior and anterior arteries and veins surrounding the humerus can often be detected, which triggers a whole cascade of pathophysiological and regulatory processes in which Interventions immediately release inflammatory mediators. Therefore, orthopedic traumatologists strive to reduce the risk of intra- and postoperative complications, and it is necessary to improve the surgical technique of surgical interventions towards their less traumatic performance.

AIM: Development and evaluation of the effectiveness of the use of low-traumatic surgical access when performing reverse shoulder arthroplasty.

MATERIALS AND METHODS: In the period 2017–2020, 169 patients with various diseases, injuries of the shoulder joint and their consequences were operated on in the Department of Adult Orthopedics of the N.N. Priorov National Research Medical Center of the Russian Federation, who underwent reverse shoulder arthroplasty according to generally accepted indications. In the main group (84 patients), surgical treatment was performed using a low-traumatic surgical approach, while the control group (85 patients) underwent standard procedures. Functional, clinical and radiological results of surgical treatment of patients of the main and control groups were evaluated and compared after 3, 6 and 12 months.

RESULTS: In the main group, excellent results (<25 points on DASH) were observed in 73 patients, good results (26–50 points) — in 10 patients. In 1 patient, the results were assessed as satisfactory (51–75 points). In the control group of observation, the clinical result was worse (68 excellent, 16 good and 1 satisfactory result).

CONCLUSION: On the basis of the performed study, taking into account the better results in the main group of patients, the technique of low-traumatic surgical access for reverse shoulder arthroplasty can be recommended for wide use in clinical practice.

Keywords: reverse arthroplasty; shoulder arthroplasty; surgical aggression; a minimally invasive method.

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INTRODUCTION

According to the early literature on shoulder arthroplasty, patients with rotator cuff failure, who underwent humerus head arthroplasty, had poor functional treatment results [1]. This negative experience was the main reason for the development of reverse endoprostheses for the treatment of patients with functional failure of the rotator cuff [1].

Over time, with the development of new implants and surgical techniques, the reverse philosophy of endoprosthesis replacement has become the driving force behind the development of contemporary design of shoulder joint endoprostheses [2]. At present, the number of reverse shoulder joint endoprostheses installed globally is several times higher than the number of hemiarthroplasty surgeries [2]. Statistical data from open registries of shoulder arthroplasty in Germany (2006–2019) and Great Britain (2012–2019) revealed that the prevalent use of reverse total shoulder endoprostheses over total anatomical and unipolar prostheses (Tables 1 and 2) [3, 4]. This tendency can be comparable with the historical development of hip arthroplasty [5].

Shoulder arthroplasty is considered a traumatic surgery and can be accompanied by several complications [2]. Some complications are related to the material, design, and correct placement of the orthopedic prosthetic systems. Some complications not associated with implants are caused by the traumatic nature of the surgical technique. During surgical interventions on the shoulder joint, iatrogenic damage to structures such as the axillary nerve and posterior and anterior arteries and veins that surround the humerus led to disorders in the innervation and blood supply to the shoulder joint structures, which manifest as muscle hypotrophy and poor functional outcomes [6]. The surgical approach, accompanied by a wide dissection of the skin and subcutaneous tissue, dissection and stratification of contracted and scarred muscle fibers, removal of pathological tissues, resection of the proximal humerus, implantation of prosthesis components, and manipulations near the main neurovascular bundles, launched a whole cascade of pathophysiological and regulatory processes in which inflammatory mediators are immediately released in the intervention zone [2].

This study aimed to develop and evaluate the efficiency of using a low-traumatic surgical approach when performing reverse shoulder arthroplasty. Owing to the desire of trauma orthopedists to reduce the risk of intra- and postoperative complications, developing methods for improving the technique of surgical interventions toward their less traumatic performance are necessary [7].

MATERIALS AND METHODS

From 2017 to 2020 in the Department of Orthopedics for Adults of the Priorov National Medical Research Center of Traumatology and Orthopedics, 169 patients with various diseases, injuries of the shoulder joint, and their consequences were surgically treated, according to generally accepted indications, underwent reverse arthroplasty. The main group (84 patients) underwent surgery using a low-traumatic surgical approach, while the control group (85 patients) received surgical treatment using standard techniques. The patients were comparable by gender, age, nosology, and degree of degenerative dystrophic changes in the shoulder joint. The deviations in these groups were not significant.

Clinical, radiological, and instrumental examinations of the patients were performed before the surgery. A clinical examination, including assessment of the pain syndrome, range of joint motion, and functional state of the deltoid muscle, was performed. With severe hypotrophy of the deltoid muscle, which often results from injuries, especially preceding surgical treatment, ultrasound examination of the deltoid muscle and electroneuromyography of the upper limb nerves were performed. With total atrophy of the deltoid muscle bundles, even reverse arthroplasty is functionally unpromising. Radiography of the shoulder joint in two projections and multispiral computed tomography of the shoulder joint with visualization of the glenoid were performed to assess its dysplasia and defects (Fig.

Table 1. Types and number of installed shoulder joint endoprostheses in the period from 2006 to 2019 according to the German Shoulder Arthroplasty Registry.

Endoprosthesis type	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total	70	69	96	157	120	137	167	177	230	228	288	203	299	250
Hemiendoprosthesis	76	58	95	134	76	44	55	52	73	72	68	45	29	37
Reverse	72	113	130	200	169	179	171	308	446	478	583	691	933	1018

Table 2. Types and number of installed shoulder joint replacements in the period from 2012 to 2019 according to the UK National Joint Registry

Endoprosthesis type	2012	2013	2014	2015	2016	2017	2018	2019
Total	627	1177	1526	1764	1891	1971	1870	1850
Hemiendoprosthesis	880	1296	1283	1055	1010	830	694	647
Reverse	678	1344	1853	2125	2742	3268	3485	3805

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1). These diagnostic methods are required for planning the preferred types of endoprosthesis components and their spatial orientation during implantation.

Based on the literature, well-known surgical techniques, and authors' own practical experience, several surgical approaches are used in reverse shoulder arthroplasty, as detailed below [6].

(1). Forty-three patients of the control group underwent reverse arthroplasty through the anterior deltoid–pectoral surgical approach. A skin incision of at least 8 cm was made in the middle of the line between the coracoid process and the anterior angle of the acromion and in the caudal direction on the tendon of the biceps brachii long head. After the skin and subcutaneous tissue were dissected, dissection was performed along the fascia of the deltoid muscle medially to the deltoid–pectoral sulcus. Then, a blunt instrument was passed through the deltoid sulcus to the clavicular–thoracic fascia medially from the cephalic vein. The deltoid muscle was retracted to the side. Despite the use of modern prosthetic systems of special instruments for installing components through this access, the technical implementation of their implantation can have several difficulties. Adequate visualization of the articular surface of the scapula with this approach is complicated, and for the correct installation of the metaglene, a widened incision may be required, thereby increasing the injury rate of the surgery. However, there are risks of iatrogenic damage to the anterior artery and vein bending around the humerus. Damage to the axillary nerve and branches of the musculocutaneous nerve is also possible.

The use of this surgical approach can be justified if there was a history of hypotrophy of the anterior bundle and functionally good condition of the middle and posterior bundles of the deltoid muscle. This is substantiated by the desire to preserve the healthy muscle tissue as much as possible, since after surgical treatment, local hypotrophy of the deltoid muscle is noted in the area of surgical access in majority of the cases.

(2) Forty-two patients of the control group underwent surgery using an external transdeltoid surgical approach to the shoulder joint. During the access, a skin incision of at least 8 cm along the outer surface of the shoulder joint was started from the outer edge of the acromial process of the scapula and was made laterally to the level of the surgical neck of the humerus. After the dissection of the skin and subcutaneous tissue, the deltoid muscle fascia was dissected. The anterior and middle bundles of the deltoid muscle were bluntly separated.

This surgical approach provided good visualization of the shoulder joint structures, namely, the proximal humerus with the supraspinatus muscle and full visualization of the scapular articular surface after resection of the humeral head. Despite the advantages of this approach over the deltoid-thoracic approach, the risks of trauma with a surgical instrument to the neurovascular formations (axillary nerve and anterior and posterior veins and arteries surrounding the humerus) persist after surgery, when they are compressed or tensioned with retractors.

(3) The main follow-up group consisted of 84 patients who underwent surgery with a minimally invasive modified transdeltoid approach. With the patient sitting on the operating table, a skin incision was made up to 6 cm from the edge of the acromion and linearly along the outer surface of the shoulder distally to the level of the greater tubercle projection (Fig. 2).

The deltoid muscle was accessed using a cutting tool; the anterior and middle muscle bundles were bluntly separated. Then, the scar tissue was excised, the humerus head was mobilized, and preliminary suturing of the tendons of the rotator muscles was performed. Then, the shoulder was rotated moderately; by applying pressure along the humeral axis in the proximal direction with the forearm bent by 90°, the proximal metaepiphysis of the humerus was dislocated and removed from the wound (Fig. 3).

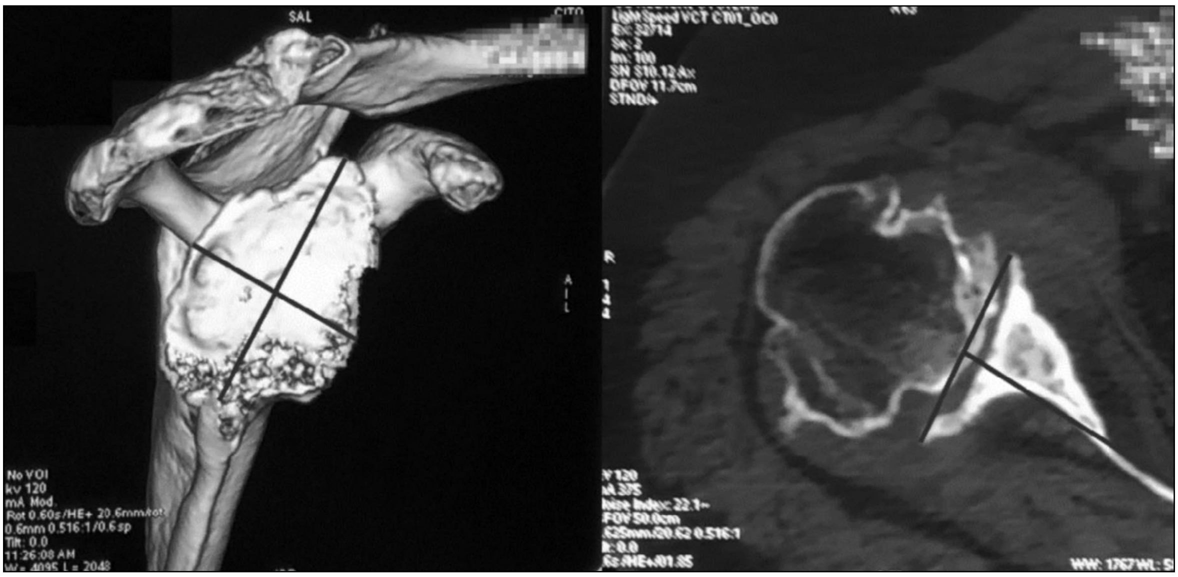

Fig. 1. Computed tomography was performed to measure anatomical parameters of the articular process of the scapula

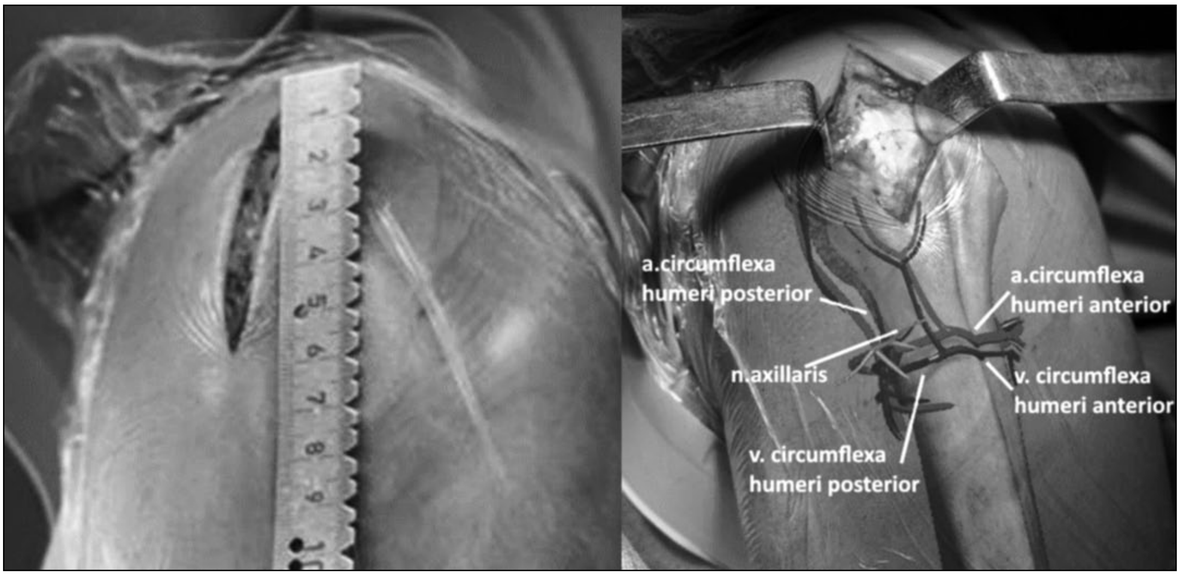

Fig. 2. Dissection of soft tissues with minimally invasive access to the shoulder joint and topography of neurovascular formations of the deltoid region in relation to the surgical access

According to the preoperative planning, the humeral head was resected, the humerus was brought down using special tools, and the wound edges were separated, thereby visualizing completely the articular surface of the scapula. Further, after sequential processing of the articular surface of the scapula with special cutters, the metaglene and glenosphere were installed, taking into consideration the inclination angle of the articular process of the scapula. The rest of the endoprosthesis components were installed according to the standard technique (Fig. 4).

If the tendons of the rotator cuff were intact, they were re-fixed, and the wound was sutured in layers. Given the economical dissection of soft tissues and the removal of the proximal shoulder into the wound, the injury rate of the surgery and risks of postoperative hypotrophy of the deltoid muscle bundles are reduced, and there are no risks of trauma to the nerve trunks and vascular formations. Moreover, the approach enables full visualization and allows work with the articular surface of the scapula and proximal humerus.

RESULTS

Initiation of early rehabilitation in the postoperative period, which included electrical stimulation of the deltoid muscle, mechanotherapy, and physiotherapy exercises, was fundamental. In the early postoperative period, none of the patients had marginal wound necrosis, hematomas, and wounds healed by primary intention. No purulent and inflammatory complications were also registered in the study patients.

The functional, clinical, and radiological results of the surgical treatment of patients in the main and control groups

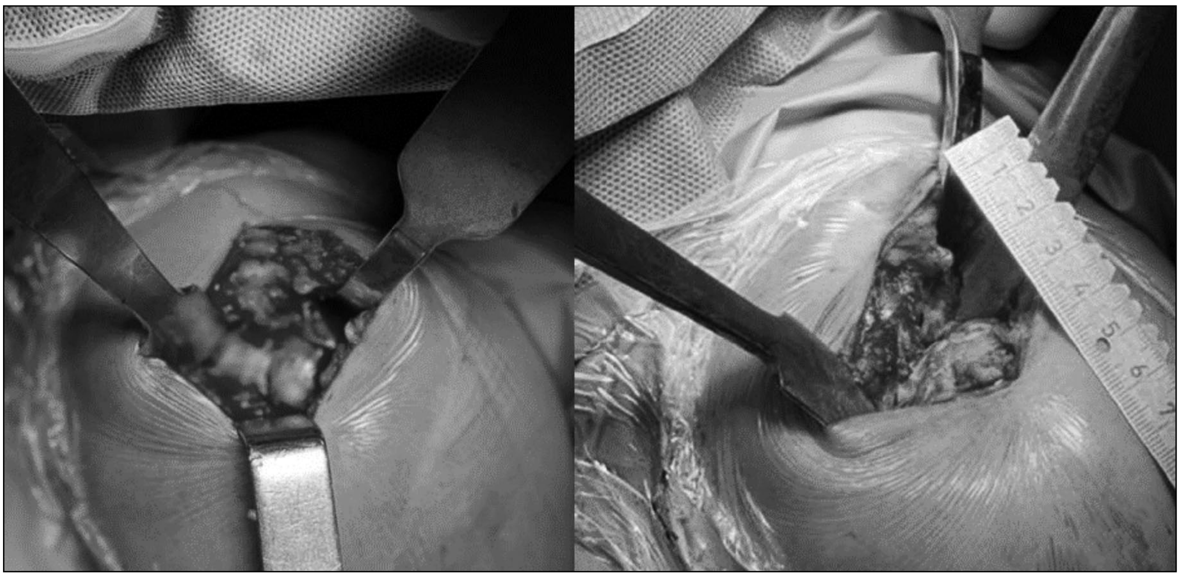

Fig. 3. Mobilization of the humerus head

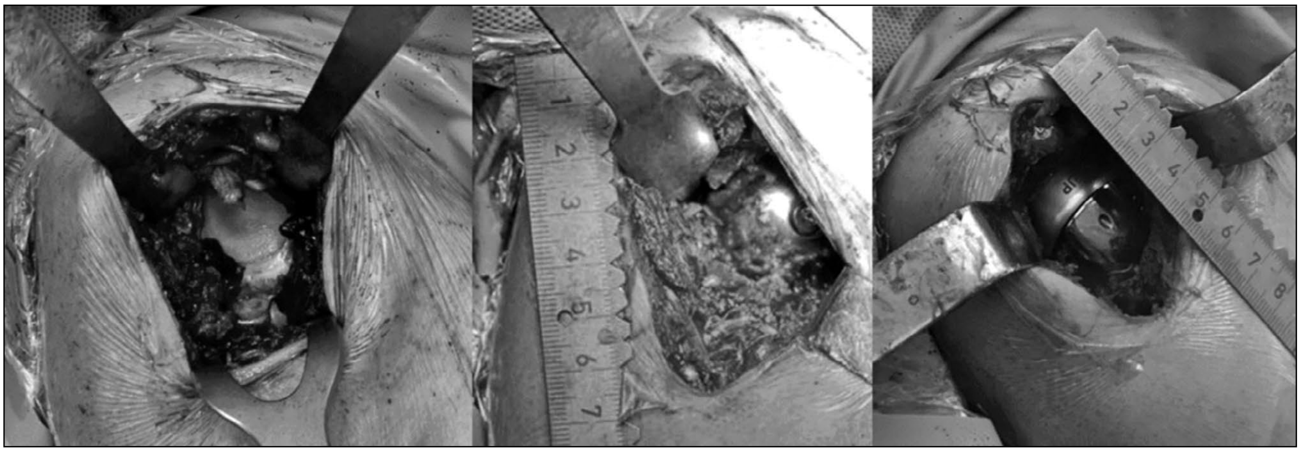

Fig. 4. Visualization of the articular surface of the scapula and installation of endoprosthesis components

were assessed after 3, 6, and 12 months. After the follow-up period, X-ray patterns revealed no dislocation, migration, or instability of the endoprosthesis components.

Functional results were assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire. In the main group, 73 patients had excellent (<25 DASH points), 10 patients had good (26–50 points), and one patient had satisfactory results (51–75 points). In the control group, the clinical result was worse, and it was excellent in 68 patients, good in 16, and satisfactory in one. Considering the absence of significant differences between patients in the groups monitored and correct installation of reverse endoprostheses according to standard techniques, the treatment outcomes were directly dependent on the surgical approach used. In the group using the minimally invasive approach, almost no hypotrophy of the muscle tissue of the deltoid region was registered; clinically and according to electroneuromyography data, the functional state of the deltoid muscle was the same compared with the healthy limb. In the control group of patients who received surgical treatment using external transdeltoid and deltopectoral surgical approaches, local hypotrophy of the deltoid muscle bundles were noted, as a result of its trauma with wide tissue separation during surgical access to the shoulder joint. With standard approaches to the shoulder joint, a comparatively large intraoperative blood loss was revealed compared with the use of a low-traumatic approach.

CONCLUSION

Given the tendency in current surgery to reduce surgical aggression and the scientific and practical development of the subject of reverse arthroplasty, the availability of modern implants enables development and selection of low-traumatic treatment approaches. The improvement of treatment results of the shoulder joint pathology depends directly on the use of methods for correcting surgical aggression. Based on the study performed, given the best results in the main group of patients, the low-traumatic surgical approach technique for reverse shoulder arthroplasty can be recommended for widespread use in clinical practice.

ADDITIONAL INFO

Author contribution. Thereby, all authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work.

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Electrophysiological patterns of sciatic nerve in patients with arthrosis deformans of the hip

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ABSTRACT

BACKGROUND: Neurological complications in sciatic nerve (SN) after a total hip replacement (THR) are observed in 0.9–3.2% of cases in patients with arthrosis deformans and age-related morphologic changes in SN. These cause the need for SN evaluation before THR. This research was aimed at the evaluation of the initial SN capacity with electrophysiological findings in patients with arthrosis deformans of the hip.

MATERIALS AND METHODS: Electroneuromyography (ENMG) was used to evaluate fibular and tibial nerves M-responses as well as F-waves in 66 patients with dysplastic coxarthrosis and 12 patients with posttraumatic coxarthrosis. The findings were compared to those of the controls.

RESULTS: Changes in ENMG findings for fibular nerve in 49 patients with dysplastic coxarthrosis were bilateral and showed significant difference only from the norm. In 19 of 66 cases (27.9%) low M-responses (p <0.02) were found in the side subject to THR. In 87.3% of cases, the signs of a decrease in the conductivity of proximal segments of the tibial nerve were revealed. In patients with posttraumatic coxarthrosis, the significant decrease in ENMG findings from both fibular and tibial nerves was observed in the affected side, they made up just 42-50% of those in the opposite side. Asymptomatic progress of denervation damage in hip and tibia muscles sometimes required needle EMG to fund the signs of motor innervation disorder. A-waves revealed in 65% of patients suggested local damage to one or both portions of SN.

CONCLUSION: ENMG findings in patients with dysplastic arthrosis of the hip enabled revealing of the signs of neuropathy before surgeries and decreasing the risk of neurologic post-surgery complications.

Keywords: sciatic nerve; arthrosis deformans; THR; hip joint; ENMG.

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ECO•VECTOR

BACKGROUND

Total endoprosthesis (TEP) of the hip joint (HJ) is becoming steadily performed worldwide; in Russia, it is 60.2% of all TEPs [1]. Dysplastic coxarthrosis accounts for up to 80% of coxarthrosis cases [2–4]. One of the complications of total hip replacement (THR) is damage to the sciatic nerve (SN), which varies from 0.9% to 3.2%. In this regard, special attention is required for patients with a history of surgical treatment for congenital HJ pathology, since the frequency of neurological complications after joint implantation is three times higher than that in patients with dysplastic coxarthrosis [5–7]. Many THR surgeries are performed on patients aged >55 years, when age-related morphological restructuring occurs even without SN failure, with a decrease in the number of nerve fibers in its bundles by 36%, the amount of connective tissue increases by 17%, and the thickness of the myelin sheath decreases [8, 9]. An unfavorable factor that also affects the state of the SN in patients with dysplastic coxarthrosis is the presence of persistent radicular lesions and myodystrophic changes in the muscles surrounding the HJ during joint replacement [10–15]. If the SN is damaged, both parts can be affected, but the peroneal region is affected more often and more roughly. This can be due to the anatomical characteristics of the peroneal region of the nerve, options for dividing the SN into regions, and a weak vascular network that supplies blood to the nerve trunk [16].

By knowing the anatomical and morphological aspects of the SN in patients with severe osteoarthritis of the HJ, before TEP, it becomes necessary to examine objectively the condition of the SN to prevent postoperative neurological complications. Meanwhile, the results of electroneuromyography (ENMG) and electromyography (EMG), which assess the state of peripheral nerves in patients with deforming arthrosis (DA) of the HJ before TEP, are not sufficiently investigated [17, 18]. The possible reason is that most patients do not show clinical signs of peripheral nerve neuropathy during the initial examination.

This study aimed to assess the initial condition of the SN and its functional activity according to electrophysiological data in patients with DA of the HJ.

MATERIALS AND METHODS

The study included 78 patients aged 36–70 (mean age, 57.5 ± 10.6) years, of which 61 were female and 17 were male. Of the 78 patients, 66 were diagnosed with stage 2–3 dysplastic coxarthrosis based on the results of clinical and radiation diagnostics and 12 patients were diagnosed with post-traumatic coxarthrosis. Of the 66 patients, nine had undergone surgery during childhood for congenital dislocation of the HJ. The control group consisted of 20 people without degenerative joint lesions and neurological complaints. The inclusion criteria were as follows: presence of stage 2–3 dysplastic coxarthrosis and post-traumatic DA of the HJ without clinical symptoms of SN neuropathy. The exclusion criterion was a history of revision total arthroplasty (reTEP).

Upon admission, all patients complained of pain of varying intensities in the area of the affected HJ, aggravated by movement and exertion, support inability of the limb, and shortening. Clinically, all patients showed relative shortening of the affected lower limb of varying severities, namely, up to 3 cm in 28 (37.3%) patients, 3 cm in 45 (60%), and over 4 cm in 5 (3%). The strength of the tibial muscles was assessed on the scale of muscle contraction strength and volume of voluntary movements and was graded 4–5 points. Weak parasthesias at the levels of the thigh and lower leg were recorded in 4 of 10 patients after fracture dislocation of the HJ and in 7 patients with dysplastic coxarthrosis. There were no restrictions on the dorsal and plantar flexion in the ankle joint.

ENMG and EMG were performed in all patients preoperatively on a Dantec Keypoint electromyograph (Alpine Biomed, Denmark) following standard research methods with the determination of motor responses (M-responses), speed of impulse conduction along the motor fibers (SICeff), and peroneal and tibial nerves from two sides. The conductivity of the proximal segments of the nerves and roots of the spinal cord was assessed by the latent period of late antidromic responses of motor neurons, i.e., LP of F-waves [19, 20].

ENMG data were compared on the sides and with the indices of the control group. Since patients with dysplastic coxarthrosis can have bilateral lesions, the affected side was the side on which the implantation of the joint endoprosthesis was planned.

Given the difference in the etiopathogenesis and frequency of neurological complications in primary and secondary (post-traumatic) DA of the HJ, the patients were distributed into two groups. Group 1 included patients with dysplastic coxarthrosis, and group 2 included patients with a history of traumatic injury to the HJ, without taking into account the degree of limb shortening.

Ethics committee. The study protocol was approved by the local ethics committee of the V.I. Razumovsky Saratov State Medical University of the Ministry of Health of Russia (No. 7 dated 02/02/2021).

The results were processed statistically using the StatSoft Statistica software package. Quantitative parameters in the study groups (prospective and retrospective) were compared using the Mann–Whitney test. The criterion for the significance of the differences was $p < 0.05$.

RESULTS

ENMG was performed upon hospital admission. ENMG data of the peroneal and tibial nerves of the patients with dysplastic coxarthrosis are presented in Table 1.

In comparison, ENMG indices of the M-responses of the peroneal and tibial nerves and LP of the F-waves of group 1 on the sides did not show significant differences. Only the

Table 1. Indicators of electroneuromyography of the peroneal and tibial nerves in patients with dysplastic coxarthrosis

Nerve (*n* = 68), side	LP, ms	Amplitude, mV	Conduction block, %	SICeff, m/s	F-wave, ms, *n* = 37
Fibular, affected	3,0±0,6	3,5±1,7***	33,6±13,3	49,6±7,5	39,5±11,3
Relatively healthy	2,8±0,6	4,14±1,4	23,2±12	50,2±11,5	42,1±5,3
Control	2,9±0,3	5,1±0,8	9,6±6,6	52,9±4,8	41,9±4,7
Tibial, affected	3,8±0,7*	7,6±2,6	44,7±23,9**	45,4±5,9	42,9±4,4
Relatively healthy	3,9±0,7	6,9±2,9	37,7±17,9	48,3±9,3	44,1±5,9
Control	2,9±0,5	9,4±1,3	9,0±6,7	55,8±4,2	45,6±3,8

Note. LT — latent time, SICeff — speed of impulse conduction along motor fibers. Significant differences between the same indicators of the affected side and the data of the control group.
**p* <0.02, ***p* <0.03, ****p* <0.015.

control group data showed significant differences in the amplitude of the M-responses of the peroneal nerve. This can be due to a bilateral decrease in motor responses in 49 (72.1%) of 68 patients. In 19 (27.9%) patients, the indicators of the peroneal nerve on the affected side were below the lower limit of the norm and were significantly different from the contralateral side (1.7 ± 0.6; $p = 0.02$) and the norm (0.00001). No significant differences in the ENMG data of the tibial nerve were noted. Results of the comparison of the M-responses of the tibial nerve recorded during stimulation at different levels provided more information. In 86.8% of the cases (59 patients), the amplitude of the proximal M-response relative to the values of the distal one decreased by more than 35%. On average, the value of the conduction block of the proximal nerve segment was 43.7% ± 23.9% ($p < 0.05$), with a maximum value of 93%.

The mean values of the impulse conduction time at the level of the tibia and S1 roots of the spinal cord, according to the LP of F-waves, were not significantly different from the control group. In 23% of the patients with DA of the HJ, asymmetry of the tibial LP of the F-waves was observed, which exceeded the permissible values and averaged 3.5 ± 0.7 ms. ENMG signs of radicular lesions were confirmed by computed tomography and magnetic resonance imaging. Changes in neuronal responses recorded for the stimulation of the peroneal nerve were manifested by the absence of F-waves in patients with an M-response amplitude <3.0 mV.

Table 2 presents the results of the primary ENMG study of the peroneal and tibial nerves of 12 patients with post-traumatic arthrosis of the HJ. Several indicators in patients with secondary DA of the HJ were different. That is, a significant decrease was found at the time of impulse conduction at the level of nerve terminals ($p < 0.002$), amplitudes of M-responses ($p < 0.002$), SICeff ($p < 0.04$), and indices of the LP of the F-waves ($p < 0.03$) in the affected side relative to the contralateral limb. ENMG indicators of the motor responses of the tibial and peroneal nerves of the affected limb were only 42.2% and 50% of the control group data, respectively.

According to the algorithm of the electrophysiological studies of patients with suspected peripheral nerve lesion, established at the Research Institute of Traumatology, Orthopedics, and Neurosurgery of the Saratov State Medical University, a needle EMG is performed after ENMG to identify signs of impaired motor innervation. Active denervation processes in the muscles of the thigh and lower leg were contraindications of TEP, regardless of the ENMG results. Thus, in the course of the studies in two patients, the M-responses of the peroneal and tibial nerves were reduced and did not exceed 1.2 and 3.5 mV, respectively. Needle EMG showed denervation activities (fibrillation potentials and positive sharp waves) in both heads of the biceps muscle of the thigh in the anterior tibial and gastrocnemius muscles. Since the ENMG and EMG signs of the lesion of both regions of the SN showed impaired motor innervation at the thigh and lower leg levels, TEP was postponed, and the patients were transferred to the neurosurgery department.

Along with quantitative indicators, the shape of the F-wave curves was assessed to study the afferent–efferent conductivity of the proximal segments of the nerves and roots of the spinal cord. Between the M-response and F-waves, additional, fixed early responses were recorded along both or one of the nerves, as A-waves with a latent period spread from 17 to 21 ms or in the form of polyphase complexes.

A-waves were more often recorded along the tibial nerve on the side of the greatest joint lesion with limb shortening of ≥3 cm or in 11 patients of group 1 (16%) and 6 (50%) patients of group 2. Repeated ENMG at early stages after the joint implantation was performed according to indications in six patients with dysplastic coxarthrosis who complained of parasthesia and decreased sensitivity along the anterior surface of the leg. The decrease in ENMG parameters did not exceed 10% of the initial data, despite the recorded A-wave in 5 of 6 patients before surgery. On day 2, one female patient with post-traumatic arthrosis of the HJ developed pain on the rear side of the thigh and weakness on dorsiflexion of the operated side of the foot. The M-response of the peroneal nerve did not exceed 0.8 mV, and F-waves were absent. The ENMG data obtained before surgery showed an M-response with an amplitude of 1.4 mV, which indicated axonal damage to the peroneal portion of the SN, but without

Table 2. Indicators of electroneuromyography of the peroneal and tibial nerves in patients with post-traumatic coxarthrosis

Nerve (n = 10), side	LP, ms	Amplitude, mV	Conduction block, %	SICeff, m/s	F-wave, ms
Малоберцовый, больная	3,2±0,8	2,4±0,9*#	44,0±11,1**,##	43,7±3,1	43,6±2,9
Здоровая	2,9±0,2	4,8±0,8	15,1±0,4	57,3±6,7	38,2±3,4
Контрольная	2,9±0,3	5,1±0,8	9,6±6,6	52,9±4,8	41,9±4,7
Большеберцовый, больная	3,5±0,5^^^	4,9±1,7^	32,5±11,7^^	52,7±3,8	47,5±3,7
Здоровая	3,0±0,8	9,7±2,4	52,4±2,8^^	48,7±3,5	44,7±2,7
Контрольная	2,9±0,5	9,4±1,3	9,0±6,7	55,8±4,2	45,6±3,8

Note. LT — latent time, SICeff — speed of impulse conduction along motor fibers.
*Significance of differences between the values of the affected and healthy sides of the peroneal nerve, p <0.002, **p <0.03; #reliability of differences between the values of the affected side and the data of the control group of the peroneal nerve, p <0.0002, ##p <0.003; ^reliability of differences between the values of the affected and healthy sides of the tibial nerve, p <0.0002, ^^p <0.01, ^^^p <0.002.

EMG signs of impaired motor innervation. Despite the ongoing physiofunctional and drug treatment based on ENMG and EMG monitoring, an increase in denervation disorders was evident within 1 month; the patient underwent SN neurolysis, followed by direct electromodulation.

Repeated ENMG performed 1 month after the implantation of the HJ in 64 patients of group 1 and 10 patients in group 2 did not reveal significant differences in ENMG data. The indices of the M-responses of the peroneal nerve were 3.5 ± 1.7 mV in the initial examination and 3.8 ± 1.3 mV in another examination. A moderate decrease in the amplitudes of M-responses, not exceeding 23% of the primary data, was noted mainly in group 2.

DISCUSSION

Analysis of the results of patients with dysplastic coxarthrosis showed that in 28% of the patients, a significant decrease in the peroneal nerve indices in comparison with the norm and contralateral limb data, indicating the presence of an axonal lesion, was noted on the side of the forthcoming TEP. Similar changes were recorded in patients who had undergone surgery for congenital dislocation of the HJ. The results correspond to the literature data that TEP has more frequent neurological complications in patients who underwent surgical treatment of HJ deformities during childhood. A decrease in the conduction properties of the proximal segment of the tibial nerve at the femur level in 86.8% of the cases and the asymmetry of the conduction times >2 ms at the L5 and S1 root level of the spinal cord in 43 of 68 patients indicated the presence of radicular disorders confirmed by the radiation diagnostics data.

In patients with post-traumatic arthrosis of the HJ, on the side of the affected joint, ENMG signs of predominantly axonal damage of not only the peroneal but also the tibial nerves were associated with traction and compression–ischemic lesions of the SN during trauma. The need for an electrophysiological study before TEP in such patients is also indicated by the asymptomatic course of the denervation processes in the thigh and lower leg muscles, identified by needle EMG. The presence of the axon reflex revealed during the study of the F-waves in 11 patients with HJ dysplasia and in six patients with post-traumatic coxarthrosis with limb shortening >3 cm indicated local branching of the axons in response to nerve compression and the presence of a locally affected area [3]. We regarded the A-wave as an ENMG sign of a local lesion of both or one of the SN regions.

Repeated ENMG 1 month after TEP did not reveal any negative changes over time in the ENMG data of both nerves in most cases, as a result of changes detected in electrophysiological data on the state of the SN in the preoperative period. However, it is not always possible to avoid neurological complications during HJ implantation in severe joint deformities [21, 22]; moreover, timely ENMG monitoring contributes to the restoration of the nerve conduction function. In the postoperative and rehabilitation periods, when the load on the operated limb increases, knowledge about the level and extent of nerve damage will help avoid an increase in pain syndrome and adjust individually the patient's rehabilitation program.

CONCLUSION

ENMG in patients with DA of the HJ in the preoperative period revealed the already existing signs of axonal lesions of predominantly the peroneal nerve, ENMG signs of local lesions of one or both portions of the SN, a decrease in the conduction function of the proximal segments of the tibial nerve, and signs of progressive neuropathy in patients with post-traumatic coxarthrosis. The results of electrophysiological diagnostics help in predicting the functional risk of neurological complications after TEP.

ADDITIONAL INFO

Author contribution. S.P. Bazhanov, V.V. Ostrovskij — concept and design of the research; G.A. Korshunova — data collection and processing, writing; V.S. Tolkachev — statistical analysis; V.V. Ostrovskij, A.A. Chekhonatsky — editing. Thereby, all authors made a

substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work.

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Competing interests. The authors declare that they have no competing interests.

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