

Reverse Shoulder Arthroplasty with *Latissimus Dorsi* Transfer for Humerus Fractures Sequelae

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Abstract

Background. Fractures of the proximal humerus occupy the 3rd place in the structure of fractures in the elderly. Failure to treat these injuries leads to irreversible changes in the shoulder. The main treatment for the latter is arthroplasty. The surgical treatment of this category of patients is still a difficult task. **The purpose of this study** was to compare the effectiveness of standard reverse arthroplasty with reverse arthroplasty in combination with the reconstruction of the external rotators of the shoulder or transposition of the *latissimus dorsi*. **Materials and Methods.** The retrospective evaluation of treatment results of 96 patients with consequences of shoulder injuries was conducted. Of these, 51 patients underwent standard reverse arthroplasty (group I), and 45 patients (group II) underwent arthroplasty with reconstruction of the external rotators of the shoulder or transposition of the *latissimus dorsi*. The female patients accounted for 68.8%. The duration of the injury varied from 8 months to 2.5 years, the follow-up — from 1 to 7 years (Me = 3.5). The results were assessed with VAS, ASES, UCLA scales. **Results.** The positive outcomes were observed in most patients. Complications: dislocations of the endoprosthesis occurred in 16.7%, infectious complications — in 5.2%, shoulder component instability — in 2.1%, fracture of the humeral diaphysis — in 3.1%, neurovascular bundle injury — in 2.1% of cases. In the patients of group I, dislocations occurred significantly more often than in the patients of group II. To reduce the risk of complications, a rational tactic has been developed for treating patients with consequences of shoulder injuries. If electroneuromyography values from the deltoid muscle were less than 40% of the contralateral side, or if mineral bone density T-score was less than 2.5 SD, arthroplasty was not performed. During arthroplasty, it is necessary to perform the direct suturing of the of the infraspinatus and teres minor tendons to the humerus. If it is impossible, the *latissimus dorsi* transfer is indicated. **Conclusion.** Reverse arthroplasty in the treatment of the humerus fractures sequelae is an effective technique. To reduce the risk of complications, it is necessary to provide the additional stability of the endoprosthesis by reconstruction of the external rotators or *latissimus dorsi* transfer. It is advisable to refrain from arthroplasty in cases of severe deltoid hypotrophy and severe osteoporosis.

Keywords: proximal humerus fractures, humerus fractures sequelae, reverse shoulder arthroplasty, *latissimus dorsi* transfer.

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Fractures of the proximal humerus in the patients over 65 years old take the 3rd place in the rate of fractures after fractures of the wrist and femoral neck [1]. Their rate increases with age and is twice as common in women as in men. This is most likely associated with the risk of osteoporosis in female patients over 50 years old [2].

Severe post-traumatic pathology of the shoulder comprises old non-fused and incorrectly fused proximal humerus fractures, including those with incomplete osteosynthesis and avascular necrosis of the humerus head, chronic fractures-dislocations of the proximal humerus, chronic shoulder dislocations with bone defects, false joints of the humeral surgical neck [3, 4].

The presence of pronounced post-traumatic changes in the shoulder complicates the choice of treatment tactics due to the multiplanar bone deformity of the proximal humerus and the absence of prospects for the restoration of the articular surfaces. The main method to treat these changes today is arthroplasty. Due to the nature of the pathology, there is often a total deficit of the rotator cuff. Therefore, arthroplasty using a reversible endoprosthesis design becomes preferable [5, 6].

There are few studies in the literature on the results of shoulder arthroplasty in the treatment of severe post-traumatic pathology. However, it is noted that the number of complications after arthroplasty due to the consequences of shoulder injuries is higher than after arthroplasty for shoulder degenerative diseases [7, 8, 9].

The most common complication of shoulder arthroplasty, when the latter was carried out for the consequences of trauma, is dislocation of the endoprosthesis [4, 8]. The search for ways to provide the additional stabilization of a reversible endoprosthesis in the treatment of the patients with the consequences of shoulder injuries is an urgent task.

The purpose of this study was to compare the efficacy of standard reversible arthroplasty without short shoulder rotators recon-

struction or muscle transfer with reversible arthroplasty in combination with reconstruction of the external shoulder rotators or latissimus dorsi muscle transfer.

Materials and Methods

It was an open retrospective cohort two-center comparative study of the surgical treatment results. The patients with consequences of shoulder injuries underwent surgery using different surgical techniques in two medical institutions (Federal Center of Traumatology, Orthopedics and Arthroplasty, Cheboksary, Russia, and Ilizarov National Medical Research Center for Traumatology and Orthopedics, Kurgan, Russia). The study included all consecutive patients treated between November 2012 and June 2018.

Patients

In total, 96 people with consequences of shoulder injuries participated in the study. The chronic injuries were represented by non-fused or incorrectly fused proximal humerus fractures, including those with incompetent osteosynthesis and humerus head avascular necrosis (n = 42); chronic dislocation fractures of the proximal humerus (n = 23); chronic dislocations in the shoulder with bone defects (n = 12); false joints of the humeral surgical neck (n = 19). Of these, 57 patients were treated and followed up at the Federal Center (Cheboksary), the remaining 39 patients – at the Ilizarov Center (Kurgan).

The study in two centers was carried out using the same protocol. The duration of the injury varied from 8 months to 2.5 years. The patients' age ranged from 57 to 81 years, the majority of the patients (68.8%) were female.

On admission, all the patients complained of dysfunction of the injured shoulder, difficulties in self-care, restrictions in the performance of work duties, and sports. Complaints of severe pain and joint contracture were most often presented by the patients with improperly fused fractures of the proximal humerus and the patients after the previous osteosyn-

thesis with signs of incompetence and necrosis of the humeral head. In contrast, the patients with false joints and proximal defects complained more about instability and hypermobility in the affected shoulder joint.

Surgical technique

All the patients underwent shoulder arthroplasty with a reversible endoprosthesis. The patients were divided into 2 groups.

The 1st group of the patients (n = 51; 53.1% of the sample) underwent a standard reverse endoprosthesis placement without reconstruction of short shoulder rotators or muscle transfer.

The patients of the 2nd group (n = 45; 46.9%) underwent reverse endoprosthesis placement in combination with the provision of additional endoprosthesis stability by reconstruction of the external shoulder rotators. The reconstruction was impossible in 9 out of 45 patients. In these patients, shoulder arthroplasty was accompanied by the latissimus dorsi muscle transfer according to the authors' method, which was developed and patented at the Federal Center (Cheboksary), (Patent RU 2725247). To do this, we used the

classic deltopectoral approach to the joint with the release of the subdeltoid and subacromial spaces. Before the endoprosthesis placement, we dissected the pectoralis major tendon at the point of attachment to the humerus, accessed the latissimus dorsi tendon, then dissected it from the humerus and released it from the surrounding soft tissues. The endoprosthesis was placed by the standard technique. Then the proximal humerus was pulled out into the wound and 4 holes in the humerus were formed 5 mm back from the crest of the greater tubercle (Fig. 1).

Non-absorbable sutures were passed through the holes. Then the endoprosthesis stem was placed. After this, the latissimus dorsi tendon was transferred behind the humerus and fixed to the latter with sutures.

Endoprostheses DePuy, Zimmer, Mathys were used in both groups.

Given the severity of the orthopedic pathology and the traumatic character of the surgery, it is preferable to perform plaster immobilization of the upper limb after these operations. The soft-woven orthosis does not provide the necessary rigidity of fixation, and the patient can remove it at any time.

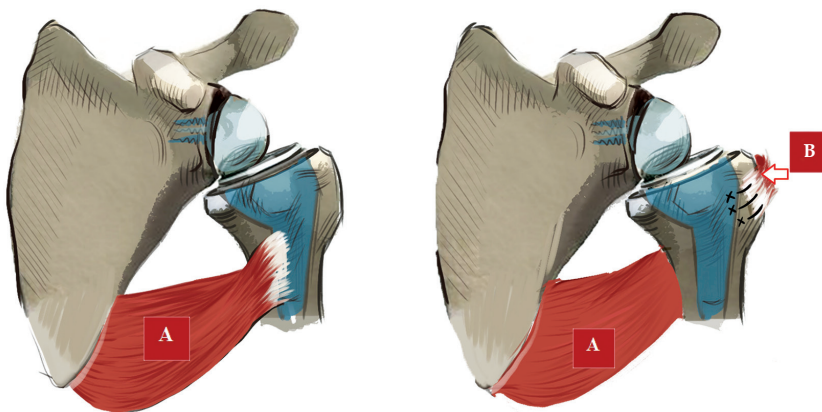


Figure. Scheme of *latissimus dorsi* transfer: A — *m. latissimus dorsi*; B — tendon fixation after transfer.

Assessment of the results

The results were assessed using functional measurements, tests, and scales. The degree of pain syndrome was assessed by VAS. The outcome of the shoulder treatment was as-

essed using the standardized University of California – Los Angeles (UCLA) Shoulder Scale and American Shoulder and Elbow Surgeons (ASES) Assessment Form.

A standard protractor was used to measure the angles of the shoulder abduction, flexion, and rotation. The shoulder abduction and flexion forces (in kg) were measured with a spring hand-held dynamometer. The multiple-planes shoulder X-ray, computed tomography, and magnetic resonance imaging were used. Electroneuromyography (ENMG) of the affected limb was performed on a four-channel digital Viking IV system (Nicolet Biomedical, USA). The intact limb ENMG indicators were used for comparison.

The bone mineral density (BMD) was determined by dual-energy X-ray absorptiometry using a Lunar DPX-NT bone densitometer (GE, USA). The patients' satisfaction with the treatment was assessed by oral questioning.

Statistical analysis

The statistical processing of the obtained data was carried out using Microsoft Excel 2007 and GraphPad programs. The correspondence of the sample values to the normal distribution in MS Excel was confirmed by a graphical method. The normally distributed data were presented in the form of the arithmetic mean (M) and standard deviation (SD). To assess the statistical significance of the differences in mean values in the groups, we used the paired Student's t-test and Fisher's exact test. Differences were considered statistically significant at $p < 0.05$.

Results

The results of the preoperative examination

On the preoperative MRI of the affected shoulders, the pronounced rotator cuff injury was revealed in most patients with non-fused and incorrectly fused fractures of the proximal humerus, including the incomplete osteosynthesis and avascular necrosis of the humeral head, as well as in the patients with chronic dislocation fractures of the proximal humerus. The absence of the rotator tendons attachment to the humerus and the signs of massive

paraarticular cicatricial adhesive process were noted. On the contrary, in the patients with chronic dislocations in the shoulder, and the patients with a false joint of the humeral surgical neck, the anatomy of the rotator cuff was preserved. These patients demonstrated only moderate fatty degeneration.

We performed preoperative ENMG of the upper extremities in 45 patients with various post-traumatic pathologies (46.9% of all cases). It was revealed that 22 of them (48.9%) had a decrease in the amplitude of the M-response from the deltoid in comparison with the contralateral limb. The pectoralis major ENMG indices on the affected side remained intact in 100% of cases. The comparison of the ENMG data before and after surgery revealed that in all cases of endoprosthesis dislocations the patients had ENMG values at the affected side less than 40% than at the unaffected contralateral side.

Functional results

Clinical and functional indicators in the study groups before and after shoulder arthroplasty are presented in Table 1. There were no statistically significant differences in the scores between the groups before surgery. The surgery made it possible to improve these indicators in both groups ($p < 0.001$); however, in the patients of the 2nd group, they were significantly better than in the 1st. As can be seen from Table 1, the majority of the patients were satisfied with the treatment. They noted the relief of pain syndrome and the improvement of joint function.

The results of the radiological examination

Osteoporosis was diagnosed before surgery in 47 patients with various post-traumatic pathology (49% of all cases). Of these, osteoporosis was absent in 5 patients (T-test -1.0 and above), osteopenia was observed in 4 patients (T-test from -1.0 to -2.5), osteoporosis in 15 patients (T-test -2.5 and less), severe osteoporosis was detected in 23 cases (T-score -2.5

and less with one or more fractures). The complications that we observed as early instability of the humeral endoprosthesis components and humeral diaphyseal fracture occurred in the patients with BMD T-score of less than -2.5 SD and a history of fractures.

Complications

The most frequent complication was dislocation in the endoprosthesis. It occurred

in group I significantly more often than in group II (Table 2).

Dislocations were not observed in all 9 patients undergone the latissimus dorsi transfer.

Differences in the rate of other types of complications between the groups were statistically insignificant. Of the 28 complications of various types, 16 cases required revision or intraoperative osteosynthesis (57.1%). In 11 patients with endoprosthesis

Table 1

Clinical scores before and after shoulder arthroplasty

Variables	Groups I (n = 51) II (n = 45)	Before surgery		After surgery		p before vs after surgery
		M (SD)	p*	M (SD)	p*	
VAS, points	I	7.5 (1.7)	>0.05	3.4 (1.3)	<0.05	<0.05
	II	7.5 (2.2)		2.6 (0.9)		<0.05
ASES, points	I	31.3 (13.8)	>0.05	58.6 (13.6)	<0.05	<0.05
	II	31.1 (12.1)		71.0 (10.0)		<0.05
Flexion, degrees	I	42.6 (18.0)	>0.05	107.2 (32.8)	<0.05	<0.05
	II	48.1 (20.9)		139.2 (25.2)		<0.05
Abduction, degrees	I	27.0 (10.0)	>0.05	79.5 (23.4)	<0.05	<0.05
	II	30.3 (19.9)		102.0 (22.3)		<0.05
External rotation, degrees	I	4.0 (5.3)	>0.05	10.1 (10.3)	<0.05	<0.05
	II	6.7 (9.6)		27.0 (10.8)		<0.05
UCLA, points	I	8.9 (2.6)	>0.05	18.7 (5.9)	<0.05	<0.05
	II	9.5 (3.0)		24.6 (5.3)		<0.05
Satisfaction,%	I	-		64.7	<0.05	-
	II	-		95.6		

* Group I compared with group II.

Table 2

Complications after shoulder arthroplasty in the patients with consequences of shoulder injuries

The type of complication	Group I	Group II	p*
Dislocation in the endoprosthesis	12	1	<0.05
Infectious complications	3	2	>0.05
Diaphyseal fracture	2	1	>0.05
Instability of the shoulder component	1	1	>0.05
Brachial plexopathy	1	1	>0.05
Total	22	6	-

* Group I compared with group II.

dislocations, revision arthroplasty was performed with liner replacement for a larger one in all 11 patients, the latissimus dorsi transfer (3 patients), and formation of the joint capsule from a synthetic polymer mesh (6 patients). In the remaining 5 patients, the endoprosthesis instability was eliminated conservatively by prolonged plaster immobilization. All 5 (5.2%) cases of periprosthetic joint infection underwent revision two-stage arthroplasty. In 3 cases of the humeral diaphyseal intraoperative fracture, the cerclage osteosynthesis was performed. The early scapular component instability required revision arthroplasty with its replacement in 2 patients. Two patients with plexopathy received long-term neurotropic therapy.

Discussion

Shoulder arthroplasty for the consequences of injuries to the proximal humerus is a complex surgery. Nevertheless, satisfactory results can be achieved in most patients [10].

According to M.F. Pastor et al., reconstructive osteotomies in the treatment of the patients with the sequelae of chronic injuries of the proximal humerus and the shoulder as a whole did not show good results [11]. J. Holton et al. searched and analyzed the articles devoted to the treatment of the patients with chronic consequences of shoulder injuries for the period from 2001 to 2016 on PubMed, Cochrane Library and Medline databases. It was found that reverse arthroplasty was the most effective technique [12]. The use of an anatomical endoprosthesis according to the indications is justified only in cases of fresh comminuted fractures of the proximal humerus and in cases when it is possible to restore the rotator cuff of the shoulder [13]. Analysis of our surgeries showed that complete restoration of the rotator cuff in the patients with chronic injury to the proximal humerus was impossible. Therefore, we did not perform anatomical endoprosthesis placement in these patients.

The only alternative is the method of arthrodesis of the shoulder, as a result of which

the pain syndrome is eliminated. However, there is no functional recovery after such an operation. According to V. Puvanesarajah et al., the glenohumeral joint arthrodesis is a technically difficult and traumatic technique that required bone grafts and original fixators [14]. We agree with the authors that this technique can only be used if arthroplasty is futile, e.g. pronounced deltoid atrophy, axillary nerve neuropathy, significant post-infectious tissue changes.

J. Holton et al. conducted a systematic literature review on the use of reverse arthroplasty for the treatment of the consequences of the proximal humerus fractures. The conclusions were presented based on the analysis of 9 articles with a total of 234 surgeries. In most cases, the positive results in terms of pain relief, range of motion and shoulder function were noticed after arthroplasty. However, there was a risk of significant complications, including dislocation (16.7%), infection (6.7%), intraoperative fracture (3%), and neurological damage (2.6%) [12].

S.J. Hattrup et al., based on the analysis of 26 reversible arthroplasty in the patients with severe post-traumatic shoulder pathology, also noted the difficulty of treatment and a high risk of complications in such patients [10].

In their study, E. Sebastia-Forcada et al. analyzed the results of reverse arthroplasty in 30 patients with shoulder injuries consequences. It was noted that 6 (20%) of them had various complications: the release of bone cement into soft tissues 2, endoprosthesis dislocation 2, fracture of the scapula acromial process 1, early shoulder component loosening 1 [15].

H.K. Vincent et al., in their studies of mid-term functional results after shoulder arthroplasty and assessment of the quality of life, noted the importance of restoration of external rotation of the shoulder as a criterion of treatment satisfaction [16]. Therefore, we consider it important in the course of treatment to provide additional restoration of active external rotation of the shoulder employing the external rotators muscle grafting or muscle transfer.

Our high percentage of complications after arthroplasty of the patients with shoulder injuries consequences correlates with the literature data. For example, S.A. Antuña et al. reported that 50% of their patients after arthroplasty for chronic shoulder injuries had unsatisfactory results [17]. P. Boileau et al. analyzed the results of arthroplasty by the Constant scale in the patients with post-traumatic changes in the proximal humerus: they were excellent in 11 (16%) cases, good – in 19 (26%), satisfactory – in 18 (25%), and poor – in 23 (33%) cases [8]. As in our study, the most common complication, according to colleagues, was endoprosthesis dislocation. In our opinion, the dislocation occurred due to the weakness of the deltoid on the affected side, lack of muscle balance to stabilize the prosthesis. An extremely important point is the intraoperative restoration of the infraspinatus and the teres minor which are the only entities that provide additional joint stabilization and active external rotation.

Our data on a decrease in the amplitude of the M-response from the deltoid in comparison with the contralateral muscle in 48.9% of patients are similar to literature data. C.P. Visser et al. noted that the rate of N. axillaris neuropathy of varying severity in the proximal humerus injuries reached 58% [18]. Therefore, at present, the patients whose ENMG values from the deltoid are less than 40% from the contralateral muscle are recommended preoperative conservative treatment together with a neurologist to restore the deltoid tone. Also, an additional treatment up to the moment of arthroplasty should be performed in patients with severe osteoporosis.

In addition to identifying various bone defects, preoperative planning should begin with determining the safety of the short external rotators of the shoulder, namely, the tendons of the infraspinatus and teres minor, since the reconstruction of these anatomical structures increases the stability of the endoprosthesis [19].

It is generally known that the main stability of a reversible endoprosthesis is provided by the tone of the deltoid muscle. However,

dislocations of the endoprosthesis (instability) are a common problem with a rate from 1.5 to 31% according to J. Chae et al. [20]. Apparently, in some situations, the deltoid cannot perform its function. It is this phenomenon that is observed in patients with chronic post-traumatic changes in the shoulder accompanied by deltoid hypotrophy. In their research, E.V. Cheung et al. evaluated the results of reverse arthroplasty in 119 patients with various pathologies, of which 11 (9.2%) were found to have dislocations after the surgery. The authors noted that the risk group for instability included the patients with post-traumatic pathology and non-union of the proximal humerus and its greater tubercle, as well as with total damage to the rotator cuff [21].

Given the literature data, it is advisable to use additional stabilization of the endoprosthesis. For this purpose, we try to perform reinsertion of the tendons of the infraspinatus and teres minor to the humerus during the arthroplasty. If they cannot be restored, we perform the transfer of the latissimus dorsi. In cases where the humeral greater tubercle is intact, the tendons of the infraspinatus and the teres minor likely retained their anatomical attachment, that is why their restoration during arthroplasty is not required, it is enough to be limited to the release. In the postoperative period, we immobilized the joint with a soft scarf bandage and prescribed early physical exercise therapy.

As our observations show, in the presence of a humeral surgical neck false joint, the rotator cuff of the shoulder is also intact since the greater tubercle is preserved. In this case, during the process of a reversible endoprosthesis placement, as a rule, it is possible to perform refixation of the tendons of the infraspinatus and teres minor to the humerus. P. Raiss et al. presented the results of arthroplasty of 32 patients with nonunion of the proximal shoulder bone, among which 11 (34%) patients had dislocations in the endoprosthesis after the surgery. Although the clinical indicators improved after the surgery significantly, the authors found an unacceptably high rate

of dislocations associated with intraoperative tubercle resection. The authors concluded that the tubercles and the attached rotator cuff should be preserved whenever possible to reduce the risk of dislocation after the total reversible shoulder arthroplasty [22].

The idea of additional stabilization of the prosthesis by transferring the latissimus dorsi tendon is not new and is reflected in scientific publications. A. Wey et al. analyzed articles on the results of muscle transfer in arthroplasty from January 1990 to March 2016 using PubMed, EMBASE, CINAHL, Medline and Cochrane Library databases. The authors argued that patients with rotator dysfunction undergone reverse arthroplasty with the latissimus dorsi transfer demonstrated the best clinical results with a complication rate comparable to conventional arthroplasty [23].

In a recently published article, I.A. Popescu et al. reported the outcomes of shoulder arthroplasty with latissimus dorsi transfer by a similar technique. They noted a significant functional improvement and a decrease in the number of complications [24].

The study limitations

A small number of observations do not allow us to reliably state the effectiveness of the technique. The operated patients require further follow-up, and the research requires an increase in the number of observations.

Conclusion

Our proposed technique can be recommended for additional stabilization of a reversible endoprosthesis by the provision of the internal muscular balance when it is impossible to restore the external rotators of the shoulder. The basis for this statement is our good clinical results. During the surgery, in addition to prosthesis placement, it is necessary to build some extra stability of the endoprosthesis using muscle grafting or muscle transfer. To reduce the risk of complications, it is advisable to refrain from arthroplasty in cases of pronounced deltoid hypotrophy and severe osteoporosis.

Consent

The patients gave voluntary informed consent for participation in this clinical study.

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Authors' contributions

N.N. Chirkov – research design and text preparation.

N.S. Nikolaev – research idea and literature analysis.

A.V. Kaminskii – data processing and text editing.

O.V. Spiridonova – collection of the clinical material.

All authors made a significant contribution to the research and preparation of the article and read and approved the final version before its publication. They agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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