

Surgical treatment of irreparable massive injuries of the rotator cuff of the shoulder jointN.N. Chirkov^{1,2✉}, V.N. Yakovlev¹, A.V. Alekseeva¹, E.V. Andronnikov¹, V.Yu. Emelyanov^{1,2}¹ Federal Center for Traumatology, Orthopedics and Arthroplasty, Cheboksary, Russia² I.N. Ulyanov Chuvash State University, Cheboksary, Russia**Corresponding author:** Nikolai N. Chirkov, surgenik@gmail.com**Abstracts**

Introduction Surgical treatment of massive non-repaired injuries of the rotator cuff of the shoulder (RCS) is associated with many difficulties for orthopedic traumatologists. Standard refixation is ineffective in these patients and there no any generally accepted treatment strategies. Therefore, there is a need to look for alternative methods of reconstruction. **The aim of the study** was to develop a new technique for the reconstruction of irreparable ruptures of the RCS, comparing its clinical effectiveness with the technique of partial reconstruction. **Materials and methods** The study included 58 patients with massive irreparable injuries of the RCS, who underwent arthroscopic reconstruction of the RCS in the time period from 2017 to 2020 at the FSBI "FCTA" of the Ministry of Health of Russia (Cheboksary). Thirty patients of group I (control group) underwent partial reconstruction of the cuff, and 28 patients of group II had reconstruction according to the technique developed by us. The essence is additional plasty of the rotators using tendon autograft from the long fibular muscle and the proximal biceps. The average follow-up period was 30.7 ± 5.6 months. The results were evaluated using the VAS, ASES, UCLA, CSS scales, X-ray and MRI data. **Results** Good and excellent results according to the UCLA-ASES-CSS scales were achieved in 53.6 % in patients of group II versus 26.7 % in patients of group I ($p = 0.036$). In group I, VAS was 2.1 ± 1.8 and in group II – 1.0 ± 1.1 ($p = 0.02$). The average value of the acromiohumeral interval was 6.7 ± 2.7 mm after using the modified RCS reconstruction technique, versus 3.6 ± 2.1 mm in the control group of patients ($p < 0.0001$). According to MRI data, the rate of full-layer repeated ruptures of the RCS tendons after reconstruction using the modified technique was significantly lower, 17.9 % versus 56.7 % in the group of partial reconstruction technique ($p = 0.002$). Four patients from group I underwent revision surgery, and two of them required arthroplasty with a reversible endoprosthesis due to the progression of arthritic changes in the shoulder joint. **Conclusion** The developed technique for reconstruction of "irreparable" massive injuries of the RCS allows restoring vertical balance in the shoulder joint, significantly improves clinical and functional indicators, reduces the number of repeated ruptures of the rotator tendons in comparison with the method of partial reconstruction.

Keywords: shoulder joint, rotator cuff, massive irreparable injury, arthroscopic reconstruction, autograft plastic surgery

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INTRODUCTION

According to available literature, a rotator cuff tear (RCT) with a MRI defect area more than 5 cm or involving two or more tendons is classified as a massive rotator cuff injury. In the cases in which it is not technically possible to surgically perform complete refixation of the RC tendons due to tendon retraction, fatty muscle infiltration, or muscle atrophy, the condition is defined as an irreparable massive rotator cuff tear [1]. Significant dysfunction of the shoulder joint is diagnosed in patients with irreparable massive RCT [2]. Methods for the treatment of irreparable RCTs are various and include both conservative and surgical treatment: tenotomy of the tendon of the long head of the biceps brachii, partial repair of the rotator cuff, balloon plasty, reconstruction of the upper joint capsule, muscle transfers, and reverse arthroplasty of the shoulder joint [3].

The most widely used method of upper joint capsule reconstruction is grafting imbedded from the upper pole of the glenoid to the greater tubercle of the humerus. Various options have been proposed as a graft: fascia lata of the thigh, tendon of the long head of the biceps muscle, cell-free dermal allograft, xenograft, or synthetic graft [4]. Despite a large number of treatment methods, the rate of poor outcomes in the treatment of irreparable RCTs remains high. Thus, Ok H.S. et al. report a re-rupture rate with reconstruction failure ranging from 17.6 % to 94 % [5].

The purpose of the study was to develop a new technique for the reconstruction of irreparable RCTs, to compare its clinical effectiveness with the conventional technique of partial reconstruction.

MATERIALS AND METHODS

Several interrelated tasks had to be solved to achieve the goal. They were united into two main periods of the study: analysis of the outcomes in the patients that had

been already treated according to conventional technique (retrospective analysis) and experimental clinical (prospective) analysis of treatment results according a

modified technique. The study included 58 patients with massive irreparable injuries of the RCS according to the inclusion criteria out of 71 patients examined who underwent arthroscopic reconstruction of the RCS in the time period from 2017 to 2020 at the FSBI "FCTO" of the Ministry of Health of Russia (Cheboksary).

Inclusion criteria were all sequential patients with irreparable massive RCTs that were confirmed by MRI, who were followed in the post-operative period, filled in standard surveys and available evaluation systems.

Exclusion criteria were severe neurologic symptoms in the upper limb and deforming arthrosis of the shoulder joint in stage 2 or 3, and complete tear of the tendon of the subscapular muscle.

The study was conducted following the ethic principles of the World Medical Association Declaration of Helsinki (Ethical Principles for Medical Research Involving Human Subjects, 2013) and rules of clinical practice in the Russian Federation (Ministry of health order 266 from June 19, 2003). All patients gave their informed consent for participation in the study.

Time from injury ranged from one year to 4.7 years and age range was from 41 to 72 years old. Males were 71.8 % of the total sample.

At admission, all patients complained of persistent pain in the injured shoulder area that worsened after physical loading and at night, difficulties of selfservice, limitations of work execution and sport activities.

Surgical interventions

Arthroscopic reconstruction of the RCTs was performed in all the patients. During surgery, arthroscopy was used to assess the rigidity of tendons, release of the injured tendons, bursectomy, and correction of associated pathologies.

Patients were included into two groups. Thirty (51,7 %) patients of group I (control group) underwent partial reconstruction of the cuff for balancing the action of the external and internal rotators.

Patients of group II (n = 28) had RCT reconstruction according to the technique developed by the authors.

To implement it, the patient was in a half-sitting position with the upper limb in lateral traction for

standard arthroscopic approach to the shoulder joint. Tendon release and anchor refixation were done if it was technically possible. The upper RC part was reinforced by involving the tendon of the long head of the shoulder biceps that was distally fixed in the region of the greater tubercle. Next, a longitudinal 2.0-cm incision was produced in the region of the lateral malleola, the tendon of the long peroneal muscle was harvested for autologous grafting. The adjusted graft was pulled through the RC soft tissues with forceps. The autogenous graft was tensioned and its ends were fixed in the area of the greater tubercle with anchor fixators. Thus, an additional loop was formed from the autograft that secured the cuff from re-rupture after reconstruction. The involved tendon of the long head of the shoulder biceps and the tendon autograft formed a structure that was like the upper capsule of the joint (Fig.1).

Evaluation of the results

Clinical results were evaluated with functional measurements, tests and scales. Standard angulometer was used to measure the angles of abduction, flexion and rotation in the shoulder joint. Abduction and flexion strength in the shoulder joint was measured by lifting graduated in kilograms loads. Visual analogue scale (VAS) was used to assess the severity of pain.

The outcomes of treatment were also assessed using validated systems:

- 1) UCLA, University of California, Los Angeles;
- 2) ASES, American Shoulder and Elbow Surgeons Assessment;
- 3) CSS, Constant Shoulder Score.

The outcome value was a total value according to which the results that coincided by using 2 systems out of 3.

A multi-positional radiography of the shoulder joint was taken to evaluate the centering of the humeral head relative to the glenoid. Therefore, the acromiohumeral interval was evaluated. If the distance was 8 to 12 mm, the centering of the humerus was normal. Moderate centration was by 6 to 7 mm. In narrowing of the acromiohumeral interval less than 6 mm, there was an upper subluxation and failure of reconstruction [6].

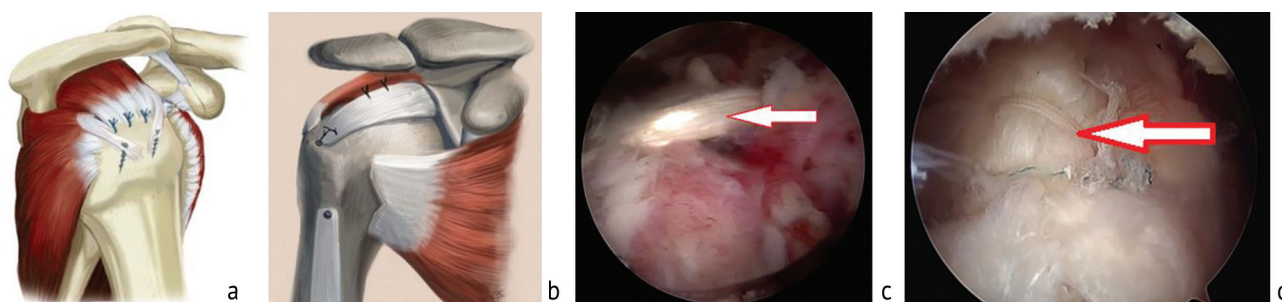


Fig. 1 Diagram of reconstruction reinforcement with an autogenous tendon of the long peroneal muscle (a); diagram of formation of the upper capsule of the joint from the tendon of the long head of the shoulder biceps (b); arthroscopic image of the part of the placed autologous tendon of the long peroneal muscle (arrow) (c); arthroscopic image of the proximal part of the biceps tendon involved into reconstruction (d)

MRI evaluation of the RCT reconstruction was performed using a simplified classification of Sugaya [7]. Reconstruction was considered viable in types I and II of the integration of the tendon with the bone. Type III of integration was judged as partial tear of the repaired tendon but an integral superficial or deep RC layer in the region of anchor fixators. Types IV and V corresponded to complete re-rupture of the rotator tendons after the reconstruction.

Statistic analysis

Data processing was performed using the developed

PC statistical programs in Excel 2010 and GraphPad Prism 8.0 for Windows 10.0 (GraphPad Software, USA) [61]. During data processing, the mean and standard deviations ($M \pm SD$) were calculated. The statistical significance of differences between the data in the absence of a normal distribution was assessed by the nonparametric Mann–Whitney U test. For qualitative data, differences were assessed using the chi-square test (χ^2). The data were considered reliable if the probability of error (p) was less than 0.05.

RESULTS

Results of preoperative examination

The result of preoperative examination were similar in both groups without significant differences. Hypotrophy of the supraspinatus and infraspinatus muscles on the affected side was noted by clinical examination of the scapular region seen as tissue depression in the area of the supraspinatus and infraspinatus fossa (Fig. 2).



Fig. 2 Clinical manifestation of the hypotrophy of the and infraspinatus supraspinatus muscles on the right side

All patients had crepitus in the affected shoulder joint. Crepitus manifested itself at the moment of friction of the exposed area of the greater tubercle of the humerus after the tear of the tendon of the supraspinatus muscle on the lower surface of the acromial process of the scapula (in abduction by 45–60°). Thus, the detection of crepitus in patients with RC ruptures allows us to consider it as a valuable diagnostic sign, according to which a full-thickness rupture of the supraspinatus tendon can be suspected.

If the infraspinatus tendon was involved in the rupture, the force of external rotation of the shoulder was significantly reduced. This symptom was detected in 68 of our patients before surgery (95.8 %). A decrease in the force of internal rotation of the relatively healthy shoulder was detected in 8 patients (11.3 %), which indicated damage to the tendon of the subscapularis muscle.

The mean VAS score before surgery was 6.6 ± 1.03 . The mean index of flexion was $98.2 \pm 38.7^\circ$, abduction was $78.7 \pm 36.5^\circ$, and external rotation was $6.2 \pm 8.5^\circ$. The average value of the acromiohumeral interval, according to X-ray data, was 2.0 ± 1.4 mm, what shows an upper subluxation of the shoulder and loss of the stability of the shoulder joint in the vertical plane.

Preoperative MRI showed signs of chronic avulsion of the tendons of the supraspinatus and infraspinatus muscles with retraction of the 3rd stage, muscular fatty degeneration and atrophy of the 3rd and 4th stages in all patients. In 9 patients, signs of partial damage to the upper third of the subscapularis tendon were additionally determined (5 patients of group I and 4 patients of group II), who underwent refixation of this tendon according to the standard technique.

Functional results after the intervention

Outcomes were assessed in 30 patients of group I and 28 patients of group II. The average follow-up period was 30.7 ± 5.6 months.

The surgical treatment improved the clinical and functional parameters in both groups ($p < 0.05$); however, in patients of group II, they were statistically significantly better compared to group I (Table 1). Thus, the rate of good and excellent results on the UCLA-ASES-CS scales in patients of group II was 53.6 % versus 26.7 % in patients of group I ($p = 0.036$). Most of the patients were satisfied with the treatment, noted relief of pain and improved joint function.

Results of imaging methods

Radiography and MRI of the shoulder joint after surgery were performed in all patients studied. In group II of a modified technique for RCT reconstruction, the average value of the acromiohumeral interval was 6.7 ± 2.7 mm versus 3.6 ± 2.1 mm in patients of the control group I ($p < 0.0001$). According to MRI data, the rate of full-thickness repeated RCTs after reconstruction using the modified technique was significantly lower than in partial reconstruction technique, 17.9 % versus 56.7 % ($p = 0.002$). Revision surgeries were performed in four patients of group I, and two of them reverse arthroplasty due to the

progression of arthritic changes in the shoulder joint. The centering of the humeral head in the horizontal plane after the operation was equally achieved in patients

of both groups, provided that the reconstruction was consistent. There were no postoperative complications in both groups of patients.

Table 1

Clinical and functional parameters after RCT reconstruction

Parameter, scale	Group I (control)	Group II (experimental)	p*
	M (SD)	M (SD)	
Number of patients	30	28	
VAS, points	2.1 (1.8)	1.0 (1.1)	0.0201
Flexion, degrees ¹	133.7 (40.5)	161.4 (16.9)	0.0022
Abduction, degrees ¹	120.3 (43.2)	152.5 (27)	0.0007
External rotation, degrees ¹	17.83 (16.8)	29.82 (15.2)	0.0061
UCLA, points ¹	22.00 (5.8)	25.86 (5)	0.0106
ASES, points ¹	57.97 (20.1)	72.46 (14.2)	0.0211
CSS, points ¹	69.73 (14.4)	80.21 (10.8)	0.0222
Subjective satisfaction, %	57.1	82.1	

* – Group I compared with Group II; ¹ – data are presented as M (SD); the significance of differences was assessed using the Mann-Whitney U test, $p \leq 0.05$ was taken as significant.

DISCUSSION

Full-thickness injuries of the rotator cuff occur in approximately 10 % of people over 60 years of age and are one of the most common causes of pain and dysfunction in the shoulder complex [8]. Patients with massive rotator cuff tears may experience severe pain, reduced joint range of motion, and limitations in daily activities. Arthroscopic repair of a massive RCT has an uncertain prognosis, since the rate of re-rupture is higher than in the reconstruction of small tears [9].

A number of techniques have been developed to improve the outcome of massive RC injuries, including the use of double-row suturing techniques, reconstructions of the upper joint capsule of the shoulder joint, muscle-tendon transfer techniques, and reverse arthroplasty. PubMed has indexed over 100 articles in the past 5 years that mention "massive rotator cuff tear" in the title or abstract. The literature on the methods shows that the most common is the reconstruction of the upper joint capsule. However, in current domestic practice the use of this technique encounters serious obstacles associated with the availability of a graft to replace a RC defect. They are associated with either with legal restrictions or with the lack of registration on the territory of the Russian Federation. In fact, the only available option for the formation of the upper capsule is the use of an autotendon from the fascia lata of the thigh. However, harvesting this autograft requires an additional large incision in the thigh area, which we consider to be an excessive aggression. Moreover, the technique of upper joint capsule formation is technically complex

and requires a large amount of materials, which limits its wide application.

The harvesting of the autogenous tendon of the long peroneal muscle is technically simple and does not require large incisions. The autotendon has greater mechanical strength compared to the allograft and has a greater potential for biological ingrowth. The advantage of the proposed technique is that, unlike the classical formation of the upper capsule, our design is a dynamic structure, since one end is fixed to the tendon of the cuff.

To manage the irreparable part of the RC, a technique of implanting a biodegradable subacromial spacer (InSpace) was proposed. It allows expanding the subacromial space and restoring the alignment of the humeral head in the cavity [10]. However, this technique, as well as the technique of reconstruction of the upper capsule, has low efficiency in case of combined injuries of the tendons of the supraspinatus and infraspinatus muscles [11].

Several myotransposition techniques have been described to treat the damaged external rotators of the shoulder joint. The most common variant is latissimus dorsi transposition. It is a traumatic and complex surgical intervention with a complex learning curve [3]. Therefore, this option for the treatment of irreparable RCTs has not been widely used. In our own surgical experience, we have always been able to arthroscopically repair the damaged external rotators of the shoulder (infraspinatus and teres minor tendons). To do this, we execute traction on the tendon and use a circular release of these structures - dissection of

fibrous adhesions, capsules and scars with a power tool to provide mobility. Fixation to the greater tubercle was carried out with 3 or 4 anchor fixators.

The choice of surgical treatment for chronic massive RCT injuries is arthroplasty using a reverse endoprosthesis design. This design of the endoprosthesis reduces and medializes the center of rotation in the joint. It becomes possible to abduct the limb due to the deltoid muscle without the participation of short shoulder rotators. However, this is a traumatic intervention and is associated with a risk of significant complications, the most common of which include dislocations in the implant, infection, and mechanical complications [12]. Therefore, we consider it unjustified to use arthroplasty if cartilaginous covering of the shoulder joint is intact.

Both our experience and available literature show that repair of the supraspinous tendon in massive RCTs is not possible due to its expressed retraction. In this situation, a variant of partial reconstruction of the injured tendons is available to balance the forces and stabilize the joint in the horizontal plane. This option has been frequently used in practice as it is technically simple and does not require additional materials. The analysis of our own clinical cases shows that in the patients of group I with partial RCT reconstruction the acromiohumeral interval

measured 3.6 ± 2.1 mm post-surgery what corresponds to a residual upper subluxation of the shoulder.

Therefore, our findings confirm that partial RCT reconstruction does not ensure the shoulder balance in the vertical plane. On the contrary, the modified technique with the use of the autogenous tendon of the long peroneal muscle together with the augmentation of the biceps provide simultaneous strengthening of the reconstructed tendons of the external rotators of the shoulder and an effect of the upper joint capsule. It is confirmed by a wider subacromial space of 6.7 ± 2.7 mm post-surgery in the patients treated with this technology. This technology also ensures a proper centering of the humeral head in the cavity. However, the efficiency of the technique still needs to be proven on a larger sample. But the results of our study demonstrate its higher efficiency compared with partial RCT reconstruction.

The technique proposed by us may be recommended for additional reinforcement of the refixed tendons of the rotators as the use of autogenous tendon for reconstruction allows shunting the stress on the fixation sutures. This is confirmed by a fewer number of RC re-ruptures after the reconstruction with the modified technique in comparison with partial reconstruction.

CONCLUSION

The developed technique for reconstruction of "irreparable" massive injuries of the rotator cuff of the shoulder allows restoring vertical balance in the shoulder joint, significantly improves

clinical and functional indicators, reduces the number of repeated ruptures of the rotator tendons in comparison with the method of partial reconstruction.

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The authors declare no conflicts of interests.