



Options in Tendon Transfers for Anterior-Superior Rotator Cuff Tears: Review

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Background. Irreparable anterior-superior rotator cuff tears can cause significant shoulder dysfunction due to the failure of normal biomechanics of the joint, because of the loss of compressive effect of the rotator cuff on the humeral head. Muscle-tendon transfers are an alternative to standard surgical treatment options: debridement of injured tendons, arthroscopic anchor suture, and reverse shoulder arthroplasty. Currently, several options of muscle-tendon transfers are described in the foreign literature, and there is an active discussion over the results of the already proposed techniques, and their improvements, while these techniques are practically not covered in the domestic literature.

The aim – to describe modern surgical technique options of the muscle-tendon transfers for the treatment of patients with anterior-superior rotator cuff tears based on a review of foreign literature sources.

Methods. The search for publications from 1988 to 2022 was carried out in the PubMed/MEDLINE and Google Scholar databases.

Results. Nowadays, the most common muscle-tendon transfers options for patients with anterior-superior rotator cuff tears are the sternocostal portion of the of pectoralis major tendon transfer and the latissimus dorsi tendon transfer. A review of foreign literature showed that muscle-tendon transfers are a well-described alternative to standard methods of treating profile patients with a predictable result.

Conclusion. Currently, there is no consensus on clear indications for certain types of muscle-tendon transfers in case of anterior-superior rotator cuff tears, there is a lack of data on long-term results. This determines the need of study of the long-term clinical results of use of these methods and develop an algorithm for choosing the tactics of surgical treatment of relevant patients.

Keywords: rotator cuff tear, muscle-tendon transfers, shoulder arthroscopy.

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Варианты сухожильных трансферов при передневерхних разрывах вращательной манжеты плечевого сустава: обзор зарубежной литературы

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Актуальность. Невосстановимые передневерхние разрывы вращательной манжеты могут значительно ухудшить функцию плечевого сустава из-за нарушения нормальной биомеханики сустава в связи с утратой компрессирующего действия вращательной манжеты на головку плечевой кости. Мышечно-сухожильные трансферы являются альтернативой стандартным вариантам хирургического лечения: дебридменту поврежденных сухожилий, артроскопическому якорному шву и реверсивному эндопротезированию плечевого сустава. В зарубежной литературе описано несколько вариантов мышечно-сухожильных трансферов для лечения этой патологии и ведется активное обсуждение результатов уже предложенных техник, а также их усовершенствование, в то время как в отечественной литературе данные методики практически не освещены.

Цель обзора — на основе анализа публикаций оценить современные хирургические техники мышечно-сухожильных трансферов при лечении пациентов с передневерхними разрывами вращательной манжеты плечевого сустава.

Материал и методы. Поиск публикаций осуществлялся в базах данных PubMed/MEDLINE и Google Scholar с 1988 по 2022 г.

Результаты. В настоящее время наибольшее распространение получили мышечно-сухожильные трансферы грудинно-реберной порции сухожилия большой грудной мышцы и сухожилия широчайшей мышцы спины, которые являются альтернативой стандартным методам лечения с предсказуемым результатом.

Заключение. В настоящее время нет единого мнения о четких показаниях к тем или иным вариантам мышечно-сухожильных трансферов при передневерхних разрывах вращательной манжеты плечевого сустава, недостаточно данных об отдаленных результатах. Это определяет необходимость изучения отдаленных клинических результатов применения данных методов и разработки алгоритма выбора тактики хирургического лечения профильных пациентов.

Ключевые слова: разрыв вращательной манжеты, мышечно-сухожильные трансферы, артроскопия плечевого сустава.

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BACKGROUND

Shoulder rotator cuff (RC) tears can have many configurations, which are classified according to the extent of damage, the involved tendons and the possibility of their repair [1, 2]. Injuries of the tendon of the subscapularis muscle may have no clinical manifestations, causing delayed treatment, resulting in retraction and fatty degeneration of the muscle belly and making the rupture irreparable [1].

The damage to the tendon of the subscapularis muscle is often associated with the damage to the tendon of the supraspinatus muscle - these injuries are called anterosuperior. In these injuries, the compressive effect of RC on the humeral head (HH) is compromised, resulting in anterosuperior translation of HH, causing pain and dysfunction of the shoulder joint [3].

Surgical treatment of patients with massive RC tears is challenging, as the high incidence of recurrent tears, ranging from 18 to 94%, the lack of engraftment after repair and the possible irreparable character of the tear lead to poor clinical outcomes of surgical treatment [4]. Surgical treatment methods used for massive irreparable RC tears include debridement of damaged tendons, partial repair, muscle-tendon transfers (MTT), reconstruction of the upper shoulder capsule, implantation of subacromial balloon spacer and reverse shoulder arthroplasty [2, 5]. MTT is an alternative for young and active patients with irreparable RC tears. In case of anterosuperior RC tears, the transfer of the tendon of the pectoralis major muscle, the transfer of the tendon of the pectoralis minor muscle and the transfer of the tendon of the latissimus dorsi muscle are used [2, 6, 7, 8].

Aim of the study – to evaluate the current variants of muscle-tendon transfers in case of anterosuperior shoulder rotator cuff tears, basing on the analysis of the foreign literature.

METHODS

Publications from 1988 to 2022 were searched in the PubMed/MEDLINE and Google Scholar databases. We used the following keywords and phrases: arthroscopy, rotator cuff, rotator cuff tear, anterosuperior rotator cuff tear, massive rotator cuff tear, irreparable rotator cuff tear,

subscapularis tendon, transfer, tendon transfer, latissimus dorsi transfer, pectoralis major transfer, pectoralis minor transfer. Forty-eight most relevant sources were selected for the analysis.

RESULTS

Surgical treatment options for anterosuperior shoulder rotator cuff tears

Surgical treatment of massive RC tears can have different objectives depending on the patient's needs, so there are different treatment techniques.

Subacromial decompression, debridement of damaged tendons and tenotomy or tenodesis of the long head of the biceps brachii are indicated in patients with low functional demands in whom the pain is the main complaint and whose shoulder function is sufficient for their daily activities [9]. Interposition techniques such as implantation of subacromial balloon spacer [10] and upper capsule reconstruction [11] aim to relieve pain and improve function restoring the biomechanics of the shoulder joint by placing the humeral head in the center of the glenoid cavity of the scapula.

Complete or partial arthroscopic suture anchor repair of RC can improve shoulder joint function and pain control [12]. The efficacy of biological factors in the treatment of patients with massive irreparable RC tears has not yet been proven [13, 14]. Use of stem cells and tendon augmentation are aimed at increasing the resistance of repaired tendons to damage and their ability to heal [15, 16].

Transposition of the tendon of the long head of the biceps brachii has been recently introduced. It is a promising alternative to the reconstruction of the upper shoulder capsule according to clinical and biomechanical studies. However, this technique is limited in patients who have already undergone a spontaneous tenotomy, so that the tendon is not available [17, 18].

The use of muscle-tendon transfers makes it possible to restore the near-normal biomechanics of the shoulder joint, reduce the pain syndrome and decelerate the progression of arthropathy, which explains the interest in these treatment methods, especially in young patients

with high functional demands. However, these interventions are difficult and require high level of surgeon's expertise, which explains very high incidence of complications in the postoperative period, including tendon tissue tears at the site of refixation (up to 38%), neurological and vascular complications [7, 19, 20].

There are five basic rules for successful muscle-tendon transfers listed in the literature. The transferring muscle must:

- have the same line of tension (force vector) as the muscle it replaces;
- have the same tension as the muscle it replaces;
- have the same excursion as the muscle it replaces;
- substitute only one function;
- have normal muscle strength [21].

Indications for muscle-tendon transfers are irreparable anterosuperior and anterior RC tears in young and active patients without osteoarthritis of the shoulder joint. Contraindications are stage III shoulder osteoarthritis, pronounced contracture of the shoulder joint, injury of the axillary nerve and brachial plexus, deltoid muscle dysfunction, infection of the surgical site, inability to follow the postoperative protocol, posteroinferior RC tears associated with the injury of the subscapularis muscle [20, 21, 22, 23, 24].

Transfer of the tendon of the pectoralis major muscle

The pectoralis major muscle adducts, flexes and rotates the upper extremity inward. It consists of two heads: clavicular and sternocostal. The clavicular head originates from the medial part of the clavicle, and the sternocostal head originates from the upper part of the sternum and from the second to fourth rib. Two heads converge near their attachment point. The sternocostal head of the muscle passes posteriorly and attaches proximally, while the clavicular head passes more superficially and attaches along the lateral edge of the bicipital sulcus [22]. The main source of blood supply is the pectoral branch of the thoracoacromial artery. Lateral and medial pectoral nerves innervate the muscle. They enter the muscle at an average distance of 12.5 and 11.9 cm from the tendon attachment site, respectively [22]. The pectoralis major muscle can be considered a good option for performing a muscle-tendon transfer

in case of anterosuperior RC tear, because it has adequate mobility potential and similar function to that of the tendon of the subscapularis muscle. However, from the biomechanical point of view, the pectoralis major muscle has a different vector comparing to that of the subscapularis due to its location in front of the chest wall, while the subscapularis is to the back [23].

In the literature, the transfer of the tendon of the pectoralis major muscle is considered the most popular intervention from the group of muscle-tendon transfers for the treatment of patients of the studied profile [21, 24, 25, 26, 27]. This technique was first suggested by C. Gerber in 1996, after that many variants of its performance were described. In some cases, the tendon of the sternocostal portion of the pectoralis major muscle is used, in others - that of the clavicular portion, in the rest – the entire tendon. Variants of positioning the transferred tendon anteriorly and posteriorly from the combined tendon of the coracobrachial muscle and the tendon of the short head of the biceps brachii muscle are under discussion [28, 29, 30, 31, 32].

It is more biomechanically advantageous to place the transferred tendon of the pectoralis major muscle posterior to the combined tendon because this position brings the traction vector closer to the vector of the subscapularis muscle. However, this position is more dangerous in terms of anatomy due to the risk of injury to the musculocutaneous nerve [1, 25, 33]. It should be noted that, according to a systematic review, only in two out of 195 cases, the surgeries were associated with neurological complications [33].

B. Elhassan et al. described in their study, published in 2008, the technique of transposition of the tendon of the sternocostal portion of the pectoralis major muscle under its clavicular portion. This technique provides the approximation of the traction vector to that of the subscapularis muscle without the risk of damaging the musculocutaneous nerve [26]. Today, this technique is the most common in surgical practice.

Regardless of the used transfer technique of the tendon of the pectoralis major muscle, significant pain reduction occurs and good results are achieved according to the patient's subjective assessment scales. However, unsatisfactory functional results, particularly the limitation of internal rotation, are observed in the long term [23, 24, 34, 35, 36].

Complications of performing the tendon transfer of the pectoralis major muscle include axillary deep vein thrombosis, residual pain at the attachment site of the pectoralis major muscle, anterior subluxation of the head of the humerus and musculocutaneous and axillary nerve dysfunction. The complication rate is about 10% [33, 34, 35, 36].

Transfer of the tendon of the pectoralis minor muscle

The pectoralis minor muscle usually originates from the third to fifth rib and attaches to the coracoid process. It stabilizes the shoulder and lowers, rotates down and inward the scapula or tilts it forward [37].

In 1997, M.A. Wirth and C.A. Rockwood Jr. were the first to describe the transfer of the pectoralis minor muscle to the lesser tubercle [38], but the results of this technique were published along with other methods without further stratification [6].

In 2013, P. Paladini et al. published the results of 27 transpositions of the tendon of the pectoralis minor muscle to the lesser tubercle along with a small cortical portion of the coracoid process to treat patients with irreparable anterosuperior RC tears. Two years after the surgery, there was no neurological damage, and the Constant Score improved significantly, by an average of 41 points ($p < 0.001$), although the muscle strength score did not increase significantly. Overall, 78% of patients returned to their daily activities. It is worth noting that the mean extent of loss in external rotation was only 11° , and only 22% of patients still had positive belly-press test [39].

In 2017, M. Cartaya et al. described arthroscopic transfer of this tendon with promising short-term results. However, the authors used this method to treat patients with Lafosse grade III subscapularis muscle injury, while grade IV and V were considered as contraindications for this procedure [40]. According to this study, the pectoralis minor muscle, due to its anatomical position and function, is a good candidate for internal rotation repair, as it has:

- better force vector compared to the pectoralis major muscle;
- adequate tendon excursion, which, in contrast to the pectoralis major muscle, is more similar to that of the subscapularis muscle [41];

- no excessive muscle tension after the performed transfer;
- minimal impact and damage to the surrounding tissues.

Despite the fact that the good short-term clinical and functional results have been reported in published studies, there are currently no reports confirming these results in the long term. In this regard, the transfer of the tendon of the pectoralis minor muscle remains an understudied and uncommon variant for muscle-tendon transfers in case of anterosuperior RC tears.

Transfer of the tendon of the latissimus dorsi muscle

The latissimus dorsi is a large fan-shaped muscle, which originates from the iliac crest, the thoracolumbar fascia and the spinous processes of the lower thoracic and lumbar vertebrae. It is attached medial to the pectoralis major muscle along the crest of the lesser tubercle of the humerus and lateral and proximal to the teres major muscle on the humerus. Its neurovascular supply comes from the thoracodorsal artery and thoracodorsal nerve [42, 43]. An anatomical study conducted by A.D. Pearle et al. in 2006 showed that the size of the safe corridor for mobilization of the latissimus dorsi muscle was 13 cm, as the thoracodorsal neurovascular bundle enters the latissimus dorsi at this level. This study also determined the relationship between the transferred tendon and the posterior branch of the axillary nerve, that once again points out the importance of an adequate formation of the posterior safe corridor for the transferred tendon [43]. The axillary and radial nerves are closest to the attachment point of the tendon of the latissimus dorsi when the arm is flexed, and farthest when the arm is rotated inward. This fact is especially important when harvesting the tendon from the point of attachment to the humerus [42, 43].

The transfer of the tendon of the latissimus dorsi is a common variant of muscle-tendon transfers for surgical correction of the studied pathology. The technique of the transfer of the tendon of the latissimus dorsi together with the teres major was originally described by J.B. L'Episcopo in 1934 and was used to correct active external rotation disorder in patients with Erb-Duchenne palsy [44]. Then, in 1988, C. Gerber et al. applied and described the trans-

position of the tendon of the latissimus dorsi as a method to restore active external rotation in patients with irreparable posterosuperior rotator cuff tears [45]. Due to the development of arthroscopic surgery of the shoulder joint E. Gervasi et al. described an arthroscopic-assisted tendon transposition of the latissimus dorsi muscle (ATTLDM) in 2007 [46]. Later, this technique received several modifications, and in 2015 B. Elhassan described the technique of anterior arthroscopic-assisted transposition of the tendon of the latissimus dorsi for the treatment of patients with anterosuperior RC injuries [47]. In terms of biomechanics, this intervention is more preferable than the tendon transfer of the pectoralis minor muscle because the traction vector of the latissimus dorsi coincides to a greater extent with that of the subscapularis muscle [21, 24, 48]. Published anatomical study proved the safety of the tendon transfer of the latissimus dorsi in regard to the neurovascular structures located at the surgical site [47]. The data have been published on the high incidence of postoperative tears of the thin and short (less than 2 mm thick and with an average length of 6 cm) tendon of the latissimus dorsi from the point of attachment on the humerus along and in the place of the tendon-muscle transition (from 5.5% to 38%), which is associated with the features of the tendon and improper choice of the point of attachment, as this may lead to the guillotine effect or the killer turn effect [49]. According to different authors, in the average follow-up period, the patients after the transfer of the tendon of the latissimus dorsi report a significant pain decrease, an improvement of the shoulder joint function, an excellent subjective assessment of intervention as well as an increase in internal rotation in comparison with the transfer of the tendon of the pectoralis minor muscle [20, 25, 27, 28, 48, 49]. Despite the fact that nowadays the literature does not contain many data on the long-term results of arthroscopic-assisted tendon transfer of the latissimus dorsi, this method seems to be quite promising.

CONCLUSION

The data obtained from the literature analysis indicate that the application of muscle-tendon transfers in case of anterosuperior rotator cuff injuries is rather promising. The most frequently used and studied are the transfer of the pectoralis major muscle and the transfer of the tendon of the latissimus dorsi muscle. Despite the fact that the studied literature could not fully differentiate the indications for various surgical options, the promising results of application of these techniques point out the necessity of their further study and implementation into the national surgical practice. More detailed assessment of mid-term and long-term clinical results of application of these surgical techniques and the development of patient treatment algorithms are required.

DISCLAIMERS

Author contribution

All authors made equal contributions to the study and the publication.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

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