Muscular Retraining and Rehabilitation after Shoulder Muscle Tendon Transfer

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KEYWORDS

• Tendon • Transfers • Rehabilitation • Shoulder • Retraining

KEY POINTS

- Rehabilitation after shoulder muscle tendon transfers requires extensive and lengthy rehabilitation of approximately 6 months.
- Rehabilitation must consider the patient preoperative function and the severity of muscular deficits to manage patients' expectations.
- Different shoulder tendon transfers have different immobilization requirements and specific restrictions to ensure optimal soft tissue healing and functional improvement.
- The final phase of rehabilitation should be individualized to optimize the patients' return to desired activities and occupation.

INTRODUCTION

Muscle tendon transfers around the shoulder involve transferring the tendon of a well-functioning muscle–tendon unit to the site of damaged muscle–tendon insertion. In turn, this restores function and strength of the injured shoulder muscle through dynamic muscular contraction and a tenodesis effect. The most common indication for muscle tendon transfers in the shoulder are massive irreparable rotator cuff tears, especially in active and relatively younger individuals, due to the high probability of treatment failure associated with rotator cuff repair. Moreover, muscle tendon transfers are also performed for deltoid muscle deficiency, which is most performed concomitantly with a reverse shoulder arthroplasty. After shoulder tendon transfer surgery, immobilization and rehabilitation of the transferred muscle tendon are crucial to optimize clinical outcomes. In this article, we will discuss in detail the rehabilitation after muscle tendon transfer procedures.

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Phys Med Rehabil Clin N Am 34 (2023) 481–488
https://doi.org/10.1016/j.pmr.2023.01.001 **pmr.theclinics.com**
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Muscle–Tendon Adaptation After Muscle Tendon Transfers

Several basic science studies have demonstrated cellular adaptations within skeletal muscles after altering the muscle length through joint immobilization or retinacular releases. Williams and colleagues[1] has demonstrated in mice models that immobilization of the soleus muscle in a lengthening position induced increased sarcomere production after 4 weeks of immobilization. Koh and Herzog[2] have reported similar adaptation after tibialis anterior muscle retinacular releases in rabbit models. When compared with controls, the tibialis anterior muscle tendons with retinacular release had increased excursion and moment arms similar to that in tendon transfers. Furthermore, the muscles exhibited increased sarcomeres 12-week after retinacular releases. However, Takahashi and colleagues[3] have found that this adaptation was asynchronous between a muscle and its respective tendon after tendon transfer procedures. In their study on 37 rabbit models, the extensor digitorum muscle of the second toe was transferred at a lengthened position. The authors found a significant increase in sarcomere numbers in the transferred muscle after 1 week of surgery. However, the tendon adaptation was delayed and resulted in an undesirable tendon lengthening by an average of 1.43 mm during 8 weeks after tendon transfer. These aforementioned studies provide insights on important muscle tendon adaptations that are relevant to rehabilitation after tendon transfers. However, further clinical and basic science studies are warranted to further elucidate the complex adaptation following tendon transfers.

Overview of Muscle Tendon Transfers Procedures

Muscle tendon transfers for posterosuperior cuff deficiency

Posterosuperior rotator cuff muscles include the supraspinatus, infraspinatus, and the teres minor. The main function of the supraspinatus is to initiate shoulder elevation, whereas the infraspinatus and teres minor are power external rotators of the shoulder. The main purpose of muscle tendon transfers for posterosuperior cuff deficiency is to restore shoulder external rotation and to a lesser extent to improve shoulder elevation. Deficiency of the posterosuperior cuff is treated with either the latissimus dorsi tendon transfer (with or without teres major), or the lower trapezius tendon transfer.

The latissimus dorsi muscle originates from the sacrum, T7-L5 spinous processes, and the 10th to 12th rib. Thereafter, it inserts on the proximal humerus just medial the bicipital groove and underneath the pectoralis major tendon. The latissimus dorsi tendon is a shoulder internal rotator. Thus, to achieve external rotation of the shoulder with a latissimus tendon transfer, the tendon has to wrapped posterior around the humerus, and it is then anchored onto the greater tuberosity or proximal humerus. Multiple studies have supported that latissimus transfers for external rotation function through active muscular contraction in addition to improving a tenodesis effect. Hensseler and colleagues[4] reported that clinically significant improvements in active external rotation with increased latissimus dorsi surface electromyographic activity during activities in shoulder elevation after 12 months of surgery. Porcellini and colleagues[5] similarly reported that external rotation lag signs resolved and increased electromyographic activation of the latissimus dorsi muscle after transfer during active external rotation after a mean follow-up of 16.6 months.

The lower trapezius tendon transfer was introduced by Elhassan and colleagues for treating massive irreparable tears of the posterosuperior cuff after its success in managing shoulder paralysis.[6,7] The trapezius muscle originates from the occiput and the C7-T12 spinous processes, and it consists of 3 parts. The upper trapezius inserts onto the posterior aspect of the distal clavicle. The middle and the lower trapezius both of

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which insert on the scapular spine. The lower trapezius tendon transfer has a similar line of pull to the infraspinatus, which contracts in phase during external rotation, forward elevation, and abduction. Moreover, the lower trapezius tendon provides better abduction and external rotation moment arms compared with the latissimus tendon transfer. In a cadaveric study by Hartzler and colleagues, the lower trapezius transfer had the highest external rotation moment arm at adduction, and it had the most similar moment to the infraspinatus and teres minor compared with the latissimus tendon transfer.[6] As such, the lower trapezius tendon offers many biomechanical advantages over the latissimus tendon when transferred for deficient posterosuperior rotator cuff.

Muscle tendon transfers for anterosuperior cuff deficiency

Muscle tendon transfer options for reconstructing the anterosuperior rotator cuff (ie, subscapularis and/or supraspinatus), include a latissimus dorsi tendon transfer with or without teres major, or a pectoralis major tendon transfer.

The pectoralis major muscle has 2 portions, the clavicular head and the sternal head. The clavicular head originated from the medial half or two-thirds of the clavicle. The sternal head originated from the sternum and the 2nd to 6th ribs.[8] Both heads insert onto the proximal humerus just lateral to the bicipital groove. The clavicular head mainly assists in shoulder forward flexion, whereas the sternal head mainly contributed to arm adduction and internal rotation. The pectoralis major transfer for the anterosuperior cuff deficiency has the longest track record with numerous variations reported throughout the literature with variable outcomes.[9–12]

The latissimus dorsi tendon transfer is our preferred method for anterosuperior rotator cuff deficiency due to several reasons. The latissimus dorsi muscle is a more appropriate muscle tendon transfer compared with the pectoralis major because its origin is from the posterior chest wall, providing a similar line of pull to the subscapularis muscle. Whereas the pectoralis major muscle originates from an anterior position, which is almost perpendicular to the line of pull of the subscapularis. In our experience, the pectoralis major transfer has failed to resolve preoperative anterior glenohumeral subluxation in the setting of subscapularis deficiency.[12]

Muscle tendon transfers for combined anterior and posterosuperior cuff deficiency

Combined deficiencies of the anterior and posterosuperior cuff present an increasingly challenging issue especially in the young and active individuals. In such patients, our preferred approach is to perform a “Parachute” procedure, which is a combination of a lower trapezius tendon transfer for the posterosuperior cuff and an anterior latissimus dorsi tendon transfer for the subscapularis.[13]

Muscle tendon transfers for deltoid deficiency

The muscle tendon transfer option for deltoid deficiency, especially of the anterior and middle deltoid portions, is a pedicled pectoralis major transfer. The main purpose of this transfer is to restore arm forward elevation through reconstructing the anterior deltoid muscle. The tendon transfer involved detaching the pectoralis major’s clavicular portion and the upper half of the sternal head from their origins. Thereafter, the harvested pectoralis major is rotated around its neurovascular pedicle, and then reattached to the lateral clavicle and the anterior acromion. This provides the transferred pectoralis major muscle with a vertical line of pull similar to the anterior deltoid muscle. Another muscle tendon transfer option for deltoid deficiency would be a pedicled latissimus tendon transfer. The main advantage of a pedicled latissimus tendon transfer is providing excellent soft-tissue coverage; however, it provides less strength and range of motions when compared with pedicles pectoralis major transfer.

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Rehabilitation After Muscle Tendon Transfer in the Shoulder

Multiple considerations must be considered during shoulder tendon transfer rehabilitation. The patient's preoperative status often predicts the amount of functional improvement after a tendon transfer surgery. This would include preoperative range of motion and the extent of rotator cuff and/or deltoid deficiency. Additionally, one must consider the type of tendon transfer performed. Patient specific demands pertaining to their desired activities and occupation might require tailored rehabilitation program. It is important to match patient expectations according to the aforementioned factors and to focus on gradual improvement.

Rehabilitation after shoulder muscle tendon transfers typically involves 4 phases. The first phase requires appropriate immobilization in an optimal position to ensure muscle–tendon healing with adequate tension. Patients are also educated on brace/cast care, bathing, and cryotherapy. The second phase focuses on initiating active range of motion in a gradual and progressive manner to learn the new muscle activation. The third phase focuses on strengthening and maximizing range of motion. The fourth phase is related to advanced strengthening and to individualize rehabilitation to specific patients' needs and occupation. **Table 1** displays a generic rehabilitation protocol after tendon transfer surgery.

REHABILITATION AFTER MUSCLE TENDON TRANSFER FOR POSTEROSUPERIOR CUFF

Phase 1 entails immobilization and maximal protection of the transferred tendon for 8 weeks. The type of immobilization differs between latissimus tendon transfer and

Table 1
Generic rehabilitation protocol after muscle tendon transfer procedures

Phase	Postoperative Week	Goals	Progression Criteria
I	0–8	Immobilization • External rotation brace for LD transfer for posterosuperior cuff • Shoulder spica cast for pedicled PM transfer for deltoid deficiency • Shoulder abduction brace for all other transfers	Complete 8 wk of immobilization
II	8–16	1. Initiate range of motion • Achieve functional passive range of motion (PROM) and active range of motion (AROM) 2. Transferred tendon retraining	• Achieve pain free AROM • Satisfactory recruitment of the transferred muscle tendon
III	16–24	1. Strengthening: gradual and progressive 2. Achieve maximal range of motion	• Continued satisfactory progress in strength • Continued recruitment of the transferred muscle tendon
IV	$\geq$24	1. Advanced strengthening to restore endurance and strength 2. Return to preferred activities and occupation	• Satisfactory clinical examination • Strength $\geq$75% of contralateral healthy extremity

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the lower trapezius transfer. The latissimus tendon transfer is immobilized in a shoulder brace with an abduction pillow. Whereas the lower trapezius transfer in an external rotation brace at 40° of abduction and 40° of external rotation (Fig. 1). The absolute goal of this phase is to protect the integrity of the repair. We advise patients to wear the brace at all times except when performing hygiene, which should be performed with assistance. We also instruct patients to avoid passive internal rotation, adduction, or extension.

Phase 2 occurs from week 8 to week 16, postoperatively, which consists of brace removal and initiating active range of motion. The goal of this phase is (1) to restore functional passive range of motion, (2) to achieve active range of motion with minimal pain, and (3) to retrain the latissimus dorsi or lower trapezius tendon as shoulder external rotator and humeral head depressor. No strengthening or active internal rotation is permitted during this phase. Therapeutic interventions are also permitted such as aqua therapy, biofeedback, and neuromuscular electrical stimulation, which aid in retraining of the transferred muscle tendons. At 12 weeks of phase 2, the internal rotation range of motion limitations are removed.

Phase 3 is focused on strengthening and occurs between 16 and 24 weeks, postoperatively. The main goals of phase 3 are to improve strength and maximize range of motion in a gradual but progressive fashion. Strengthening exercises are started in a supine position to eliminate gravity using bands, and light free weights. Strengthening should focus on all shoulder and periscapular muscles.

Fig. 1. The external rotation brace typically used after lower trapezius tendon transfer with the arm placed at 40° of abduction and 40° of external rotation.

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Phase 4 starts after week 24 and is concerned with advanced strengthening and return to activity. The goals of this stage are to increase endurance and strength of the transferred muscle tendon. Another goal is to enhance neuromuscular control through focusing on advanced closed chain exercises, and proprioception activities such as position awareness and rhythmic stabilization exercises. Patients are permitted to return to their desired activities after a satisfactory physical examination and when strength is achieved at 75% or more compared with the contralateral side.

REHABILITATION AFTER MUSCLE TENDON TRANSFER FOR ANTEROSUPERIOR CUFF

Phase 1 consists of immobilization with a shoulder brace with an abduction pillow for 8 weeks to protect the transferred tendon in an internal rotation position. Patients are educated on brace care, cryotherapy, and advise patients to wear the brace at all times.

Phase 2 occurs between weeks 8 and 16 postoperatively where the brace is removed, and active range of motion is initiated. Two important considerations are to perform shoulder flexion in internal rotation and to refrain from external rotation beyond neutral for 8 weeks. The goal of this phase is to (1) restore functional passive range of motion, (2) to achieve active range of motion with minimal pain, and (3) retrain the latissimus dorsi or pectoralis major tendon as shoulder internal rotator and humeral head depressor. Therapeutic interventions are also permitted such as aqua therapy, biofeedback, and neuromuscular electrical stimulation.

Phase 3 is focused on strengthening and occurs between 16 and 24 weeks, postoperatively. The main goals of phase 3 are to improve strength and maximize range of motion in a gradual but progressive fashion. Phase 4 starts after week 24 and is concerned with advanced strengthening, return to activity, and to enhance neuromuscular control. Patients are permitted to return to their desired activities after a satisfactory physical examination and when strength is achieved at 75% or more compared with the contralateral side.

REHABILITATION AFTER A COMBINED ANTERIOR AND POSTEROSUPERIOR TENDON TRANSFERS

The shoulder is immobilized using an abduction shoulder brace with neutral rotation for an 8-week duration. Between 8 and 16 weeks, rehabilitation is focused on active-assisted range of motion exercises and aqua therapy. At 16-week postoperatively, progressive stretching and strengthening is initiated for another 8 weeks to attain maximum range of motion and strength. Patients may resume their full activities without limitations at 6 months postoperatively after a satisfactory physical examination and when strength is achieved at 75% or more compared with the contralateral side.

REHABILITATION AFTER A PEDICLED PECTORALIS MAJOR TRANSFER FOR DELTOID DEFICIENCY

Phase 1 immobilization consists of shoulder spica cast for a period of 8 weeks. The arm remains in a flexed position of 45° to 60° with neutral rotation to 40° of external rotation, similar to singing into a microphone (Fig. 2). After 8 weeks, the brace is removed, and patients are advanced to phase 2.

The second phase of rehabilitation starts between week 8 and week 16 and focuses on initiating gentle passive range of motion, starting active-assisted range of motion and aqua therapy for a total of 8 weeks. The goal of phase 2 is to achieve minimal

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Fig. 2. A shoulder spica cast with the arm position in a flexed position of 45° to 60° with neutral rotation to 40° of external rotation, similar to singing into a microphone.

pain with active range of motion, restore functional passive range of motion, and retrain the transferred pectoralis major as a shoulder flexor.

Phase 3 starts between 16 and 24 weeks, which consists of gentle strengthening and with bands and light free weights starting in supine position and focusing on shoulder elevation. Phase 4 starts at 6 months with activity as tolerated and a weight restriction of 15 lbs in any direction. Gradual, progressive stretching as tolerated can occur at this point and is prohibited before this point to prevent muscle stretch injuries.

SUMMARY

Muscle tendon transfer procedures in the shoulder require a detailed and lengthy rehabilitation to achieve satisfactory outcomes. Surgeons and physical therapists must gain in-depth understanding for each tendon transfer procedure such as immobilization requirements and specific restrictions at each rehabilitation time point. Additionally, one must consider the patient preoperative function and the severity of muscular deficits to manage patients' expectations and focus on gradual but progressive improvement. Individualized therapeutic interventions must be actively implemented to help patients achieve their goals and return to their desired function.

CLINICS CARE POINTS

- Posterosuperior cuff deficiency is treated with a lower trapezius or latissimus dorsi tendon transfer, and it is immobilized for 8 weeks with an external rotation brace.
- Anterosuperior cuff deficiency is treated with an anterior latissimus dorsi transfer or pectoralis major transfer. Subsequently it is immobilized for 8 weeks in a shoulder brace with an abduction pillow.

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- If combined muscle transfers for anterior and posterior cuff deficiency is performed, patients should be immobilized for 8 weeks in a shoulder abduction brace in neutral rotation.
- Pedicled pectoralis major transfers are performed for deltoid deficiency and requires immobilization for 8 weeks in a shoulder spica cast with the arm in 40-65° forward flexion, and arm external rotation up to 40°.
- After the immobilization period is completed, patients are advanced through additional three stages consisting of gradual range of motion, strengthening.

DECLARATION OF INTERESTS

The authors have nothing to disclose.

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