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ROTATOR CUFF REPAIR (M TAO AND M TEUSINK, SECTION EDITORS)

Rotator cuff repair: post-operative rehabilitation concepts

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Abstract

Purpose of review With improvements in surgical techniques and increased knowledge of rotator cuff healing, there was a need to identify a safe progression after rotator cuff repair. The rehabilitation specialist plays an integral role in the care of these patients, and by implementing an evidence and criteria-based model, patients may be able to return to their prior levels of function sooner with fewer complications.

Recent findings Timing of progression for rotator cuff patients should align not only with healing but also potential strain on the involved tissue. Recent electromyography studies have identified exercises which elicit highest level of muscle activation for individual dynamic stabilizers. The physical therapist should also be aware of potential complications and be prepared to manage appropriately if they should arise.

Summary During rehabilitation after rotator cuff repair, there should be constant communication with the surgical team. Awareness of complication management, healing potential of the repaired tendon, and anatomy of the shoulder complex are critical. During the early stages, reducing pain and inflammation should be prioritized followed by progressive restoration of range of motion. When advancing range of motion, progression from passive, active assisted, and active movements allow for gradual introduction of stress to the healing construct. Even though time frames are not used for progression, it is important not to place excessive stress on the shoulder for up to 12 weeks to allow for proper tendon-to-bone healing. As exercises are progressed, scapular muscle activation is initiated, followed by isometric and lastly isotonic rotator cuff exercises. When treating overhead athletes, advanced strengthening in the overhead position is performed, followed by plyometric training. Advanced strengthening is initiated when all preceding criteria have been met. It is important that patients are educated early in the rehabilitation process so that they can manage their expectations to realistic time frames.

Keywords Rotator cuff · Shoulder · Post-operative rehabilitation

Introduction

Shoulder pain results in over three million visits to physicians each year. Of these visits, rotator cuff disease is the most common cause [1]. Yamamoto et al. [2] showed 20.7% of 1366 shoulders had full-thickness rotator cuff tears in the general population with the biggest risk factors being age, dominant arm, and history of trauma. Even with advances in surgical management of rotator cuff injuries, recurrent tears of large or massive repairs remain a problem, in some cases ranging from 13 to 94% [3]. It is imperative that patients not only have extremely skilled surgical care but a knowledgeable and experienced physical therapist to help guide their post-operative progression. Successful treatment of rotator cuff repair relies on constant communication between the surgical and rehabilitation staff. The ultimate goal of post-operative rehabilitation after rotator cuff repair is to relieve pain and restore range of motion as well as prior levels of function. In order to properly treat this group of patients, a sound understanding of anatomy, biomechanics, and evidence-based exercise progression are essential.

This article is part of the Topical Collection on *Rotator Cuff Repair*

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Anatomy

The rotator cuff is composed of a group of four muscles and tendons that surround the shoulder. These include the supraspinatus, infraspinatus, subscapularis, and teres minor which function to assist in glenohumeral (GH) elevation and rotation. When working together, this group of muscles creates force vectors which provide dynamic stability to the GH joint by maintaining centralization of the humeral head within the glenoid fossa. The supraspinatus plays an important role in GH joint stability and is responsible for initiating abduction and rotation of the joint as well as compression at lower elevation angles [4]. The infraspinatus and teres minor make up the posterior rotator cuff and are largely responsible for external rotation of the shoulder as well as providing an inferior compression force of the humeral head in the glenoid, which helps minimize subacromial impingement. The subscapularis works to internally rotate the shoulder and provide compression as well as anterior stability. When functioning properly, the rotator cuff complex allows for GH movement with stability; however, if the rotator cuff becomes damaged or torn through injury or disease, dysfunction may occur.

Complications

Although surgical techniques have improved and post-operative rehab techniques have advanced, complication management should be addressed. In a recent systematic review, the most frequently encountered complication was re-rupture or re-tear of the repair, ranging from 11 and 95%, followed by stiffness and hardware-related complications which ranged from 1.5 to 11.1% [5]. Numerous authors reported stiffness as the most common complication ranging from 2.7 to 15% [6, 7]. Other reported complications include nerve injury, reflex sympathetic dystrophy, infection, hardware failure, deep venous thrombosis, and complications related to anesthesia. Although these other complications have been reported, post-operative shoulder stiffness remains one of the most common issues and one that clinicians should be cautious of during treatment [8].

Rehabilitation guidelines

Initial phases of rehabilitation emphasize tissue healing, reduction of inflammation and pain, and protection of the repair. Immediately after surgery, patients are placed in an immobilizer, typically between 4 and 6 weeks. Pain and inflammation have been reported to inhibit shoulder musculature which is why the post-surgical team should make every effort to use cryotherapy and other modalities as necessary [9]. Appropriate range of motion after surgery is important in order to minimize chances of developing post-operative stiffness. As range of motion is achieved, proper exercise progression should be followed in order to limit stress on the healing repair. Throughout this process, healing of the rotator cuff repair should be respected. The healing process is divided into three stages: inflammation (0–7 days), repair (5–14 days), and remodeling (> 14 days) [10]. One primate study showed an almost mature tendon-to-bone healing by 15 weeks after surgery. By 8 weeks, initiation of collagen alignment and organization was noticed. Sharpey fibers which hold the tendon and bone together did not appear in any considerable number until 12 weeks suggesting that excessive tension on the repair be avoided for 12 weeks post-surgery [11].

Proposed rotator cuff repair guidelines

(May be adjusted according to size of tear and quality of tissue)

Phase 1 (weeks 0–6)

- ROM
  - FF to tolerance
  - ER to 60° with arm in scapular plane
  - IR: None
- Weeks 0–2 weeks strict immobilization
  - Distal hand and wrist activity
    - Squeezing, AROM hand and wrist
- Weeks 2–4: continued immobilization
  - PROM initiated by patient in scapular plane
    - 90° FF
    - 30° ER
  - Continued hand and wrist exercises
  - Elbow AROM with arm at side
  - Scapular protraction/depression
- Weeks 4–6: DC immobilizer
  - PROM/AAROM with PT
    - Flexion, ER
  - Supine PROM shoulder elevation
- Criteria to advance
  - Pain-free PROM
  - FF beyond 120
  - ER beyond 30

Phase 2 (weeks 7–11)

- ROM
  - FF to tolerance
  - ER to tolerance
  - IR to beltline: no aggressive stretching
- Week 7: progress AAROM ➔ AROM
  - Supine Cane FF in scapular plane

- Incline cane FF ➔ standing cane
- Towel slide scaption
- Isometric exercise
  - ER/IR/Ext
- T band rows with retraction

• Week 8:
- Standing shoulder extension

• Criteria to advance
- Full, pain-free PROM
- Full AROM without compensation, no shoulder "shrug"
- Pain-free isometric exercises

Phase 3 (weeks 12+)

• ROM
- FF unrestricted
- ER unrestricted
- IR unrestricted

• Week 12: strengthening
- T band ER/IR with towel
- Standing row
- Supine punch
- Side lying ER
- PNF diagonals
- Prone mid and low traps

Role of the scapula

The importance of the scapula is often underemphasized during rehabilitation of the shoulder. The scapula plays an essential role in shoulder function and stability of the glenohumeral joint. In patients with shoulder injuries, alterations in scapular position and motion have been reported 68–100% of the time [12]. As the humerus is moving through space, it is important for the scapula to move as well to maintain centralization of the humeral head in the glenoid. The scapula has the capacity to move in three planes which include the ability to elevate/depress, protract/retract, upward/downward rotation, internally/externally rotate, and tip anterior/posterior around the thorax [13]. Alterations in scapular position will commonly lead to shoulder dysfunction which is why all associated impairments must be addressed. Dysfunction of the scapula has been termed "scapular dyskinesis" and has been classified by Kibler as type I, II, and III; type I is identified as prominence of the inferior medial scapular border, type II, prominence of the medial scapular border and abnormal rotation, and type III, superior translation of the scapula and prominence of the superior medial border [14]. In the early phases of post-operative rehab after rotator cuff repair, the patient can safely be placed in a side-lying position with the shoulder unweighted and perform scapular neuromuscular education activities with manual cues if needed. If this is started early in the post-surgical care, by the time rotator cuff specific exercises can be initiated, a sound scapular foundation has already been established.

Range of motion

During post-operative rehabilitation, it is important to protect the repair, promote tendon-to-bone healing, and minimize gapping between the tendon edges and its bony insertion. Early and immediate passive motion after surgery was once believed to help reduce post-operative stiffness; however, recent animal models suggest that this immediate motion can be detrimental. Immediate post-operative immobilization has been seen to result in better tendon–bone healing than immediate post-operative mobilization [15]. Another animal model has shown that immediate early passive motion should be avoided and that delayed passive motion had no negative effect on the strength and maturity of the remodeled tendon [16]. Early passive motion may stimulate excessive matrix formation and increased scar formation in the subacromial space which leads to worsening passive shoulder mechanics, increased stiffness, and loss of motion [17]. A 2-week period of immobilization helps extracellular matrix represent similar characteristics of uninjured tissue. This period of immobilization results in increased type I collagen organization and less scar formation compared to early mobilization, concluding that the quality of tissue improves with decreased loads. These decreased loads on the tissue during early healing may provide a protective environment that allows for proper tendon-to-bone integration [18].

As passive range of motion (ROM) is initiated after a 4–6-week period of immobilization, knowledge of strain on individual muscles and tendons can be beneficial. It is important to minimize activation and strain of the repaired tissue, which is why passive motion is performed first followed by active assisted and lastly active motion. After repair of the supraspinatus tendon, tensile strength of the rotator cuff significantly decreases when the arm is elevated more than 30° in the scapular plane. Strain significantly increases as the arm is lowered from 30° to 0° of elevation [19]. Using a towel roll or support under the patients elbow when they are supine can help unload the repaired supraspinatus, and the patient should be educated to do the same at home when they are in the supine position to minimize strain. During passive elevation in the scapular plane, supraspinatus force remained near zero; however, forces were higher with the arm placed in the sagittal plane [19]. The clinician should make every effort to provide ROM in the scapular plane to minimize stress. The scapular plane can easily be described as 30° from the midline. While advancing shoulder flexion, although strain decreases, redundancy in the soft tissue has potential to cause impingement or

irritation in the subacromial space. As therapists progress into increased ranges of glenohumeral flexion, caution must be taken not to force beyond its point of first resistance and avoid end-range discomfort or pain.

In the scapular plane, glenohumeral external rotation ranging from 0° to 60° constitutes a safe zone of motion which also puts minimal stress on a repaired supraspinatus. Increased external rotation beyond 60° has the potential to cause increased tension in the anterior portion of the tendon [20]. Significant increase in strain has been reported with internal rotation stretching after RC repair and therefore should be avoided [19]. Electromyographic (EMG) analysis of the supraspinatus confirms that therapist assisted shoulder elevation and external rotation, and pendulums performed by the patient are truly passive as these motions elicit activity similar to resting levels [21•]. However, EMG data reveals that with incorrectly performed pendulums moderate activity of the supraspinatus is generated and therefore may be avoided in early rehabilitation programs to minimize chance of patient error [22]. When correctly performing pendulums, the patients position themselves slightly bent over, supported with their non-surgical arm. Shifting their bodyweight forward and backwards allows the arm to swing in a controlled manner with the assistance of gravity and not active muscle contraction. If pendulums are to be utilized, proper patient education and monitoring should be implemented to avoid unwanted activation of the rotator cuff.

Although less common than supraspinatus, an injury to the subscapularis requires additional precautions. After a rotator cuff repair involving the subscapularis, precautions may change due to the portion of tendon that was repaired (superior vs. inferior). During forward flexion, there is minimal lengthening in the superior portion, whereas strain is increased on the inferior portion. With external rotation, there was increased strain on both portions of the tendon. Repair to the superior portion of this tendon would be favorable and a safe zone of forward flexion ranges from 0° to 90°. With repair to the inferior portion, forward flexion should be avoided in the early post-operative period to minimize stress on the repair. Also, any external rotation beyond neutral is contraindicated for this population [23•].

Exercise progression

During strengthening of the rotator cuff, it is important that centralization of the humeral head is maintained and every attempt should be made to prevent superior migration. Superior migration of the humeral head, observed as a "shrug" during exercises can promote impingement of the healing tissue in the subacromial space. This "shrug" sign is also an indicator to the clinician that there is insufficient activation of the rotator cuff and altered mechanics within the glenohumeral joint. During strength progression, scapular positioning and muscle activation will be addressed since it is equally important in the recovery of this group of patients. Proper posture after surgery and sufficient muscle balance between scapular upward and downward rotators must be established. Scapular retraction and downward rotation can increase subacromial space and help promote a healing environment.

During activity progression, patients are taken from passive to active assisted and finally active exercises in order to gradually load the repaired tissue in a slow and safe manner. EMG evidence suggests that forward bow exercise as well as supine PROM with the opposite hand all had very low levels of activity on the supraspinatus. Supine PROM by a therapist elicits very low and safe levels of supraspinatus and infraspinatus activity. During the forward bow exercise, the patients have their hand and forearm supported on a flat surface and step away from the hand allowing for passive shoulder elevation [24•]. Murphy [21•] also showed low EMG activity in both supraspinatus and infraspinatus in therapist-assisted elevation, self- and therapist-assisted ER, and isometric IR. Whereas, pulleys, scapular retraction, and isometric ER all elicited EMG levels of supraspinatus and infraspinatus above baseline and are categorized as active exercises, not to be used in early rehab protocols.

Once patients display minimal-to-no reported pain, acceptable passive ROM approaching 120° elevation in the scapular plane and tolerance of passive exercises without compensation, a transition to AAROM and upright activities can commence. When transitioning out of the gravity-eliminated position, exercises that place moderate stress on the rotator cuff tendons should be performed prior to high-stress activities. Safe active assistive exercises in this phase include supine wand flexion, progressed to incline wand flexion, and finally standing-assisted flexion along with ball rollout. Wall walk exercises elicited higher supraspinatus activation and should be used in late stages of AAROM prior to active forward elevation. Supported vertical wall slides generate less EMG activity and may be a better option than wall walks in the early stages [25•]. A preferred exercise of the author in this phase is a wall slide with a towel in the scapular plane which will promote co-contraction of the shoulder stabilizers while training shoulder elevation. As patients progress, wall slide with lift-off and eccentric lowering is initiated and finally active shoulder flexion in the scapular plane monitoring for a "shrug" sign throughout the available range of motion.

The goals of intermediate phases of rehabilitation are to restore full ROM while adding basic and functional strengthening to combat immobilization and deconditioning. Selecting exercises that engage the rotator cuff as a co-activator rather than in isolation may benefit the patient while decreasing risks of complication. Isometric exercises performed in sub-maximal and sub-painful levels are initiated

starting with internal and followed by external rotation. During this time, scapular exercises are initiated as well. Standing-resisted shoulder extension and prone extension along with seated and prone row have all been shown to elicit high EMG levels of the targeted muscles without harmful strain on the supraspinatus [25•].

During later stages of rehabilitation, advanced rotator cuff exercises are initiated. Following our healing principles that excessive strain prior to 12 weeks may be harmful, we can now progress exercise that load the supraspinatus. External rotation(ER) at 0° abduction with a towel has been reported to produce activation up to 41% of maximum voluntary isometric contraction (MVIC) and may be initiated. Side-lying-resisted ER, diagonal exercises as well as prone horizontal abduction, and external rotation are all appropriate for this later stage [25•].

As the rehabilitation program evolves, strengthening should become more targeted toward the rotator cuff. EMG studies [26] comparing various positions for external rotation show highest activation of supraspinatus during ER performed at 90° abduction in the cocking position, suggesting this exercise may best be implemented toward the later stages of rehabilitation. Additionally, prone ER in 90° abduction followed by side lying ER with resistance showed highest activation of the infraspinatus. Conversely, IR performed in 90° abduction has been shown to have higher activation of supraspinatus, infraspinatus, and subscapularis when compared to IR at side [27]. As expected, when moving into a more advanced and sport-specific position required for overhead athletes, the demands of the rotator cuff increase as does its activation. These exercises should be reserved for end-stage rehab for athletes and may not be ideal for those who do not need to return to a throwing sport. Although they have the highest MVIC for the rotator cuff showing best isolation, they are also performed at end range and in a position that may provoke impingement should the patient not have the appropriate motion or control.

While rotational strength is important in post-operative rehab, it is also important to consider the contractile tissue involved in scapular stability. These muscles help control dynamic scapular motion, provide force couples, and a foundation for the shoulder joint. Most noted in the research is the concept that over activation of the upper trapezius and under activation of the middle and lower trapezius promote poor scapular position and shoulder impingement. Impairment of the serratus anterior also causes altered scapular kinematics and will also promote shoulder impingement if not addressed. Ideal exercises in shoulder rehab enhance activation of the abovementioned muscles with minimal input from the upper traps. High serratus anterior activation has been reported with supine punch performed at 90° and 120° [28]. Hardwick et al. [29] showed the wall slide to be an effective exercise to engage the serratus anterior at elevation angles of 90° and above. The wall slide was performed with the ulnar borders of both arms in contact with the wall at 90° of elevation. The shoulders were elevated in a plane approximating the scapular plane. The subjects were instructed to slide the forearms up the wall, while leaning into it by transferring body weight from the non-dominant foot to the dominant foot. High middle trap activity occurs with prone rowing and prone horizontal abduction at 90°. Greatest lower trap EMG activity has been reported in prone full can, prone ER at 90° abduction, bilateral external rotation, and prone horizontal abduction at 90° with ER [30]. Side-lying ER has also been shown to have high levels of lower trap activity, which may be useful as it also has high activity of the posterior rotator cuff [31]. The rhomboids play a role as scapular retractors and depressors and are engaged during most of the abovementioned exercises. In addition to the above exercises, prone extension and prone row have high EMG activity of the rhomboids and should be included in shoulder strengthening programs [32].

Conclusion

Rehabilitation after rotator cuff repair must follow criteria-based progression taking into account healing of the repaired tissue. With a firm understanding of the anatomy, healing properties, strain, and tissue loading, programs can be individualized to each patient. It is imperative for the patient to understand these guiding principles as well so that realistic expectations can be established and desired outcomes can be achieved in a timely manner.

Compliance with ethical standards

Conflict of interest Both authors declare that they have no conflict of interest.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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