
CLINICAL COMMENTARY
PARTIAL ARTICULAR SUPRASPINATUS TENDON
AVULSION (PASTA) LESION. CURRENT CONCEPTS
IN REHABILITATION

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ABSTRACT

Rotator cuff pathology can contribute to shoulder pain and may affect the performance of sport activities, work, and activities of daily living. The partial articular supraspinatus tendon avulsion (PASTA) lesion represents a very common type of rotator cuff pathology seen in rehabilitation. When conservative treatment fails, surgery is generally required. Success of recovery depends on several factors, including: repair techniques, healing process related to timing, rehabilitation programs, and patient compliance with home exercises. To date, most treatment modalities and rehabilitation programs are based on clinical experience rather than scientific evidence. Therefore, the purpose of this clinical commentary is to provide an overview on the PASTA lesion, discuss the common treatment approaches adopted to date and to propose a rehabilitation program based on the available scientific evidence.

Level of Evidence: 5

Keywords: Rehabilitation, rotator cuff, shoulder

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INTRODUCTION AND BACKGROUND

Partial-thickness rotator cuff tears (PTRCTs) are a common cause of shoulder pain, limitations in activities of daily living (ADL), and time off from work.^{1,2} It has been reported that the incidence of PTRCTs is between 17% and 37% in the population^{3,4} and up to 80% in patients in their eighth decade of life.^{1,5} PTRCTs were difficult to diagnose before magnetic resonance imaging (MRI) and shoulder arthroscopy, therefore most scientific research has focused on full-thickness rotator cuff tears (FTRCTs). PTRCTs are generally classified according to their location and arthroscopic appearance. The partial articular supraspinatus tendon avulsion (PASTA) lesion is a type of PTRCT and is far more common than bursal-sided or intratendinous partial tears.⁷⁻¹¹ According to Gratsman and Milne¹³ PASTA lesions comprise 91% of all PTRCTs. PASTA lesions are commonly found in overhead athletes, younger people^{12,13} and patients who smoke.¹⁴ Although the natural history of PASTA lesions remains unclear, this variety of tendon disruption is generally associated with pain and disability and it has been shown that 53% of PASTA lesions tend to enlarge.¹⁵ Both surgical techniques and postoperative rehabilitation are essential to optimize recovery. However, significant variations exist between surgical options and rehabilitation protocols. Therefore, the purpose of this clinical commentary is to provide an overview on the PASTA lesion, discuss the common treatment approaches adopted to date and to propose a rehabilitation program based on the available scientific evidence.

ANATOMY

The glenohumeral is a delicate ball-and-socket joint. Movement of the shoulder complex can be grossly divided into scapulothoracic and glenohumeral motion. The scapula provides a bony base for muscle attachments and load transfer. Abnormal scapulothoracic motion may be a factor that increases the risk of impingement syndrome and PTRCTs.^{16,17} Stability of the glenohumeral joint is provided by the joint capsule, ligaments, bony anatomy, and the negative pressure within the joint space. The rotator cuff provides compression of the humeral head on the scapula, increasing the stability of the joint.¹⁸ The muscles that form the rotator cuff are: supraspinatus, subscapularis, teres minor and infraspi-

natus. The supraspinatus muscle originates on the posterior aspect of the scapula, superior to the spine and inserts directly on the greater tuberosity of the humerus close to the articular surface. The lateral insertion of the supraspinatus is overlapped by the tendon of the infraspinatus, fusing the two into one structure.^{19,20} The subscapularis is the largest muscle-tendon unit. It originates on the anterior aspect of the scapula and inserts on the medial aspect of the biceps groove. The teres minor originates on the posterior surface of the axillary border of the scapula and inserts on the inferior-posterior aspect of the greater tuberosity of the humerus. The infraspinatus lies on the posterior aspect of the scapula. It originates inferior to the spine of the scapula and inserts on the greater tuberosity of the humerus, wrapping around the posterior aspect of the supraspinatus tendon. The subscapularis provides anterior stability and internal rotation motion to the humerus²¹ while the supraspinatus, teres minor and infraspinatus make up the posterior aspect of the rotator cuff which is responsible for abduction and external rotation of the shoulder.^{1,17,21,22}

PATHOPHYSIOLOGY

Mechanisms leading to rotator cuff injury are still under debate. Generally, PTRCTs occur at the junction of the inferior part of the supraspinatus and the superior part of the infraspinatus, leading to the PASTA lesion.²³ Most clinicians think that intrinsic, extrinsic and traumatic factors are all possible causes of PASTA tears. Among the intrinsic factors, changes in rotator cuff vascularity and metabolic changes associated with aging seem to play an important role. Some authors have shown that the size of the vessels are larger and more prevalent on the bursal side of the rotator cuff while the articular surface of the rotator cuff is relatively hypovascular.²⁴ Results of histological studies have also shown that collagen is thinner and not as well organized on the articular surface of the rotator cuff when compared to the bursal surface of the rotator cuff,²⁴ leading some authors to believe that the articular cuff is only one half as strong as the bursal counterpart.²⁵ Alternatively, some authors that believe extrinsic and traumatic factors are primary contributors to in the development of PASTA lesions. Shear stresses that affect the supraspinatus tendon due to narrowing of the

coracoacromial arch (extrinsic impingement) have been identified as a plausible cause of rotator cuff injury as they may generate a laminated disrepair of the surfaces of the cuff.¹³ Repetitive microtrauma may also cause articular surface tears especially when associated with overhead activities.⁶ Internal impingement as termed by Walch and colleagues²⁶ has been demonstrated as another possible reason for the PASTA lesion in overhead athletes. It occurs due to the repetitive contact of the articular surface of the supraspinatus and infraspinatus tendons with the posterosuperior part of the glenoid during arm abduction and lateral rotation.^{23,27,28} Many authors believe that anterior shoulder micro-instability is contributory to internal impingement and to PASTA lesions although rotator cuff injuries have been demonstrated in otherwise stable shoulders.^{26,27}

CLINICAL DIAGNOSIS

Clinical diagnosis of PASTA lesion can be difficult as not all PASTA lesions are symptomatic.²⁹ Pain is generally present in the arc of motion between 60° and 120°. ⁶ Some authors have reported that PTRCTs can be more painful than FTRCTs.^{30,31} It has also been reported that pain may be correlated with increased levels of Substance P in the subacromial bursa rather than the extent or the depth of the tear of the tendon.³² Pain is generally provoked by resisted abduction with the shoulder positioned at 90° of abduction, in the plane of the scapula and in either internal or external rotation as in the empty/full can test. However, when considering pain as a symptom for detection of supraspinatus tendon tear Itoi et al suggest the utilization of the full can test.³³ A positive lag test should make the clinician think of a FTRCT rather than PASTA lesion.³⁴ Impingement tests such as those proposed by Neer and Hawkins may be positive.¹³ If impingement tests are positive, the internal rotation resistance strength test may be utilized to help distinguish between outlet (Neer) and non-outlet (internal) impingement. With the shoulder positioned at 90° of abduction, at approximately 80° of external rotation and with the elbow bent at 90°, external and internal rotator muscles are tested with a resisted isometric contraction. A sign of apparent weakness of internal versus external rotation of the shoulder is considered positive for non-outlet (internal) impingement.³⁵ For the over-

head athlete, the clinician should also look for subtle signs of shoulder instability. Apprehension and relocation tests may be used during the examination although the presence of pain without apprehension is an unreliable finding for shoulder instability, as it is quite common in many other shoulder disorders.³⁶⁻³⁸ Physical examination findings for PASTA lesion can be non-specific and difficult to distinguish from other shoulder conditions. It has been reported that 30% of PASTA lesions occur concomitantly to other shoulder disorders.^{26,39} As a result, imaging modalities are essential for definitive diagnosis of the PASTA lesion.

IMAGING

A combination of imaging modalities is generally used for the assessment of PASTA lesion as no single imaging study has been shown to be particularly accurate. Radiographs, including an anteroposterior view of the shoulder, an axillary lateral view and a supraspinatus outlet view are sometimes used. However, they are more appropriate for assessing acromionclavicular lesions or glenohumeral disorders than PASTA lesions.⁴⁰

Ultrasound imaging is an appropriate technique for assessment of rotator cuff tears and has been proved to be valuable for diagnosis of both FTRCTs and PTRCTs.^{41,42} It should be considered the best option considering safety, cost, and accuracy for FTRCTs.⁴³ However, sensitivity of ultrasound imaging for PTRCTs is lower than magnetic resonance imaging (MRI).⁴⁴

Although MRI techniques have recently improved the ability to detect subtle rotator cuff tendon abnormalities, findings of the MRI should be interpreted cautiously as false-negative results when compared to arthroscopy have been reported in a previous study.¹³ MRI has demonstrated high sensitivity and specificity (0.90) for FTRCTs,⁴³ but poorer sensitivity for detection of partial rotator cuff tears.⁴⁴ The clinical relevance of MRI is further limited as many individuals older than 40 years of age who demonstrate abnormal rotator cuff findings on MRI are symptom-free at the clinical evaluation.²⁹ Thus, signs of partial rotator cuff tear on MRI could be an incidental finding in symptomatic as well as in asymptomatic patients.

CLASSIFICATION

PTRCTs are defined as definite disruption of fibers of the tendon and not simply fraying, roughening, or softening of the tendon surface. Tears can be classified with regards to the involved tendon, the location (articular, bursal or intratendinous) and the size, represented as the percentage of the tendon thickness torn or the vertical component relative to the tendon thickness. Although there is not a classification system specifically designed for PASTA lesions, two main rotator cuff tear classification systems are generally utilized. Ellman⁴⁵ described the lesions of the rotator cuff tendon according to the location of the tear (articular surface, bursal surface and intratendinous) and the extension of the tear. Grade 1 tears are smaller than 3 mm, Grade 2 tears are between 3 and 6 mm, while Grade 3 tears involve more than one half of the cuff tendon thickness (generally more than 6 mm).

Snyder and colleagues^{39,40} have adopted a similar classification system based on the location of the tear (A = articular surface, B = bursal surface, C = complete) and on the arthroscopic appearance (grades from 0 to 4). Grade 0 represents a normal cuff. In Grade 1 there is minimal superficial fraying in an area smaller than 1 cm. Grade 2 signifies fraying and failure of the rotator cuff tendon in an area smaller than 2 cm. In Grade 3 there is fraying and fragmentation of the entire surface of the tendon. Grade 4 tears are characterized by a stable flap tear that often encompasses more than a single rotator cuff tendon that is larger than 3 cm.

The management of PASTA tears remains controversial. Most surgeons agree with the concept that treatment of PASTA lesions varies according to the stage and the pathology and should begin with conservative treatment. However, when more than one half of the thickness of the supraspinatus tendon is involved (Ellman or Snyder Grade 3) surgical repair in symptomatic patients is indicated.^{11,46}

The final choice informing treatment for PASTA lesions should consider clinical evaluation, imaging findings, and classification of the tear. Treatment options are either conservative or surgical.

CONSERVATIVE TREATMENT

Treatment should start with physical therapy. Rest or activity modification with the avoidance of the movements that elicit pain should be included from

the early stage of the management. Oral non-steroidal anti-inflammatory drugs may be beneficial for reduction of pain and inflammation⁴⁷ although they are less effective than corticosteroids in terms of pain reduction.⁴⁸ However, it is important to note that both non-steroidal anti-inflammatory and corticosteroid drugs may have deleterious effects on long-term tendon healing.^{49,50}

Although commonly utilized to manage rotator cuff tears, many physical modalities and manual therapy techniques lack validated research that justifies their use. Laser therapy has been widely studied on several tendinopathies with mixed results. It has been suggested to be beneficial for shoulder tendinopathy⁵¹ and superior to therapeutic ultrasound in terms of pain reduction.^{52,53} Therapeutic ultrasound seems to help reverse the tendinosis⁵⁴ and appears beneficial for calcific tendonitis of the supraspinatus.⁵⁵ However, it has been shown to be no more effective than placebo for soft tissue disorders of the shoulder.⁵⁶ Transcutaneous electrical nerve stimulation (TENS) for shoulder disorders has not been studied as much as laser and therapeutic ultrasound. It has been shown to be effective for post-surgical pain,⁵⁷ but there is paucity of evidence regarding its effectiveness for PASTA lesions.

The use of joint mobilization techniques such as accessory movements and joint glides can be applied to assist in decreasing pain, muscle guarding, and restoring range of motion (ROM) deficits.⁵⁸ Although joint mobilizations and mobilizations with movement have been found to not be superior to supervised exercise and to physician advice,⁵⁹ manual therapy techniques to the glenohumeral joint seem to have positive effects across all painful shoulder conditions.⁶⁰ A recent review investigating adults suffering of non-specific shoulder pain demonstrated that spinal manipulations and spinal mobilizations also help improve self perceived recovery when compared to usual care.⁶¹ Myofascial massage of trigger points located in the shoulder girdle soft tissues seems to be more effective than placebo in terms of pain and shoulder function in patients suffering from shoulder disorders.⁶²⁻⁶⁴

Once pain is manageable, physical therapy should proceed to restoring ROM deficits and strengthening of relevant muscle groups with particular focus on

the scapular stabilizers and rotator cuff muscles,^{65,66} initially avoiding those exercises that maximally activate the supraspinatus muscle-tendon unit. Stretching techniques should be performed in those patients with total arc of motion limitations, particularly in the overhead athletes with glenohumeral internal rotation deficits due to posterior capsule tightness.^{67,68}

Restoration of neuromuscular coordination and core stability is also beneficial and important to restore the mechanisms of load transfer and for the avoidance of scapulothoracic dyskinesia.^{69,70} It is in fact well known that upper extremity motion occurs with consistent synergistic muscle activation patterns in the legs and trunk.^{71,72} Therefore, it is important to remember that scapular muscle force couples requires core strength and facilitation by the activation of the whole kinetic chain.^{73,74}

As there is not a treatment algorithm for PASTA lesions and no evidence regarding the evolution of non-operative treatment, the outcome of conservative treatment is unknown. However, the results of one study indicate that there was a progression of the rotator cuff tear in 80% of the patients who were treated non-operatively.¹⁵ This would suggest that surgical treatment for PASTA lesion should be considered.

SURGICAL TREATMENT

As spontaneous healing of PTRCTs is unlikely or poor,^{15,75} surgery is often required. Surgical treatment of PTRCTs generally involves one of the following: arthroscopic debridement of the tear, debridement with acromioplasty, and rotator cuff repair with or without acromioplasty.⁷⁶

There is controversy whether debridement with or without acromioplasty is a sufficient treatment option for PTRCTs. Budoff et al⁷⁷ reported excellent results while more recent investigations have shown that although pain may get better,⁷⁸ a large portion of PTRCTs evolve to deterioration of the lesion leading to FTRCTs.⁷⁹

If a significant articular-sided tear is present and there is a significant healthy portion of the bursal side of the tendon still intact, some surgeons may prefer to repair the tear by making a small per-

foration in the rotator cuff as a method to place medial anchors. This is a safe and effective modern arthroscopic technique that restores the anatomy of the damaged rotator cuff by securing the articular side of the tendon back to its original footprint while preserving the undamaged bursal side of the tendon.⁷⁹⁻⁸¹ Attempts to preserve the bursal side footprint of the rotator cuff as in the trans-tendon repair technique has been shown to enhance healing and clinical outcomes.⁸¹⁻⁸⁵

In some cases when only 25% of supraspinatus tendon remains attached to the bone, surgeons may prefer to complete the tear from a PTRCT to a FTRCT and treat it using suture anchors. However, when conversion to FTRCT is performed, there is a high rate of re-tear. It may be due to formation of scar tissue and lack of restoration of fibro-cartilaginous connection in the bone-tendon attachment.⁸⁴ Regardless the surgical approach; post-surgical rehabilitative management is key.

POST-SURGICAL TREATMENT

In addition to the surgical technique adopted by the surgeon, knowledge of the histology and biology of the healing process is paramount as it guides the therapist to rehabilitation programs that optimize healing rate and improve clinical outcomes. Authors suggest that tendon healing consists of three overlapping phases: inflammation, proliferative/repair and remodeling.^{16,86,87} Following surgical tendon-to-bone fixation, there is an inflammatory phase where type-III collagen synthesis is initiated over the surgery site. After a few days, growth factors induce cellular proliferation and matrix deposition. After approximately six weeks, the tissue begins remodeling where there is organization of the scar tissue and a higher proportion of Type-I collagen is synthesized.⁸⁸ However, remodeling repair tissue does not reach maximal tensile strength before 12-16 weeks after surgery.⁸⁹ It is important to remember that during the rehabilitation program progression, the mechanical properties of the repairing fibrous tissue are weaker than the native tissue⁹⁰ and that it prone to failure and re-tear may occur in up to 12% of the cases.⁸⁶

The following sections report the evidence of common post-operative treatment options and present

an evidence-supported program for the post-surgery treatment of PASTA lesions.

Immobilization and early versus delayed range of motion

Post-surgical stiffness is one of the most common complications occurring after rotator cuff surgery regardless the surgical technique adopted and it is likely linked to prolonged immobilization.^{91,92} However, research results supporting immobilization timeframes, or early or delayed ROM after surgical repair of rotator cuff tears are still controversial. Animal studies indicate that immobilization may reduce the tension over the rotator cuff repair and may help improve the collagen orientation^{93,94} although it can cause deterioration of a tendon as it decreases the protein synthesis⁹⁵ and increases the collagenase activity.⁹⁶

The optimal timing for initiation of ROM remains under debate. There are some authors that, regardless of the prolonged healing process required for a tendon-to-bone repair, suggest that early mobilization can be safely applied.^{97,98} Early mobilization is also considered to help recover ROM more rapidly in those patients who undergo arthroscopy for cuff repair.⁹⁹ Other authors suggest that there is no difference between early and delayed joint mobilization after arthroscopic cuff repair^{100,101} for stiffness and ROM and that prolonged immobilization up to six weeks or delayed ROM is not a concern for joint stiffness.^{102,103}

Research has been extensively conducted on repair of FTRCTs but not for PASTA lesions, therefore, there are no recognized indications regarding immobilization and ROM timing. However, patients with PASTA lesions should be mobilized as early as possible as it has been suggested that arthroscopic repair of PASTA lesions is a risk factor for post-surgery stiffness.¹⁰⁴

Cryotherapy

Cryotherapy is generally used post-surgery to decrease pain, inflammation and swelling. Adie et al¹⁰⁵ examined the effects of cryotherapy after total knee arthroplasty, showing the benefit of reduction of blood loss and pain although the improvement may not have been clinically significant. Authors have also shown that the use of cryother-

apy after shoulder surgery decreases the need for narcotics and that patients are better able to tolerate rehabilitation¹⁰⁶ and to return to normal sleeping patterns.¹⁰⁷ Although the use of cryotherapy is still under debate, most believe it advisable for use in the immediate post-surgical timeframe.

Regenerative techniques

Tissue regenerative strategies involving the use of mesenchymal stem cells, growth factors and platelet rich-plasma may be potentially effective therapies to enhance bone-to-tendon healing after shoulder surgery. Promising results have been reported in both animal and *in vitro* studies including: a better orientation of the fibrocartilage fibers, improvement of mechanical resistance¹⁰⁸ and tendon healing.¹⁰⁹ Ellera Gomes et al¹¹⁰ published the only investigation on the effects of stem cells in rotator cuff tears in humans to date. They investigated 14 patients with a complete tear of the rotator cuff repaired in a trans-osseous fashion thorough a mini-incision augmenting the suture with stem cells. At 12 months, according to clinical and magnetic resonance findings, 12 of the 14 tears had healed. However, the use of these new augmentation techniques on rotator cuff tears should still be considered experimental because both surgical costs and lack of validated basic and clinical research.¹¹¹⁻¹¹⁵

PROPOSAL OF A POST-SURGERY PROGRAM FOR PASTA LESIONS

As every PASTA lesion and every patient is unique, several considerations must be taken into account when building a rehabilitation program for optimal results. The rehabilitation program should be evaluation-based and should consider size of the tear, surgical technique, healing process timing, surgical findings, patient age, and the patient's goals. Therefore, the following five-phased program serves as a guideline that should be individualized for each case and adapted to each patient.

Phase I

The main goals of this stage are to enhance the structural repair, control pain and inflammation, increase ROM, and prevent muscular atrophy. During this phase, a sling should be worn for about two weeks in order to maintain integrity of the repair site and

to encourage rotator cuff healing¹¹⁶ and it should be removed only for self-care and wound cleansing. It has been suggested that the shoulder should be immobilized in the scapular plane at 45° of shoulder abduction as this position enhances regional blood flow and minimizes the passive tension on the repair site by reducing the distance between the origin and the insertion of the supraspinatus muscle.¹¹⁷ It is important to keep good mobility and strength in the elbow, wrist and hand while initiating a preliminary rehabilitation program. As collagen deposition increases 10 days after surgery and reaches a plateau at about 56 days after surgery,¹¹⁸ passive mobilization that excessively stresses the newly formed collagen network should be avoided. However, passive motion in a controlled manner within a safe ROM is beneficial as it positively affect the orientation of the collagen fibers^{90,91,119,120} and may minimize potential joint stiffness.¹²¹ Exercises should be passive initially and then assisted by tools such a wand. An example of passive ROM consists of repetitions of closed kinetic chain (CKC) shoulder flexion with the support of a table (Figures 1 A-B). While standing in front of a table, place the hands on the table and step away as far as comfortable, hold the position and go back

to the initial position. CKC exercises increase joint approximation, stimulation of mechanoreceptors and dynamic stability of shoulder complex,^{122,123} resulting in an improvement of kinesthesia.¹²⁴ Pendulum exercises are also usually utilized in this phase. Standing with the trunk bent and the good arm placed on a table for stability, the patient swings the affected arm while drawing circles (Figure 2). An electromyographic analysis demonstrated that the activation of the supraspinatus muscle is less than 10% when small diameter circles are performed.¹²⁵

Manual therapy including glenohumeral distractions and anterior and posterior glides to the glenohumeral joint with the shoulder in the resting position can be used to restore ROM since glides have been shown to be safe during the initial stages of rehab, without altering stress on the repaired supraspinatus tendon.¹²⁶ Shoulder function and pain may also be improved with sternoclavicular joint mobilization.¹²⁷ Mobilization of the scapula may be useful in the initial stages as it may help break down adhesions and release muscle guarding, improving general function of the shoulder and decrease pain. However, it does not appear to be more effective than placebo and supervised exercise.^{128, 129}

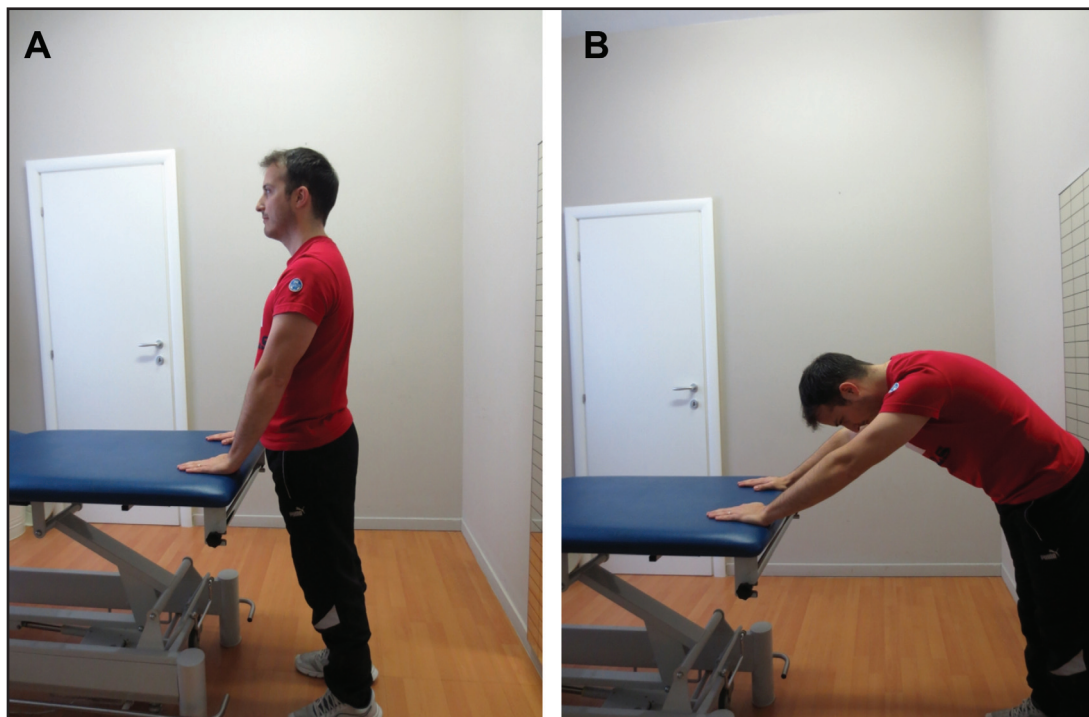


Figure 1 A-B. CKC shoulder flexion on a table. Initial (A) and final (B) positions.

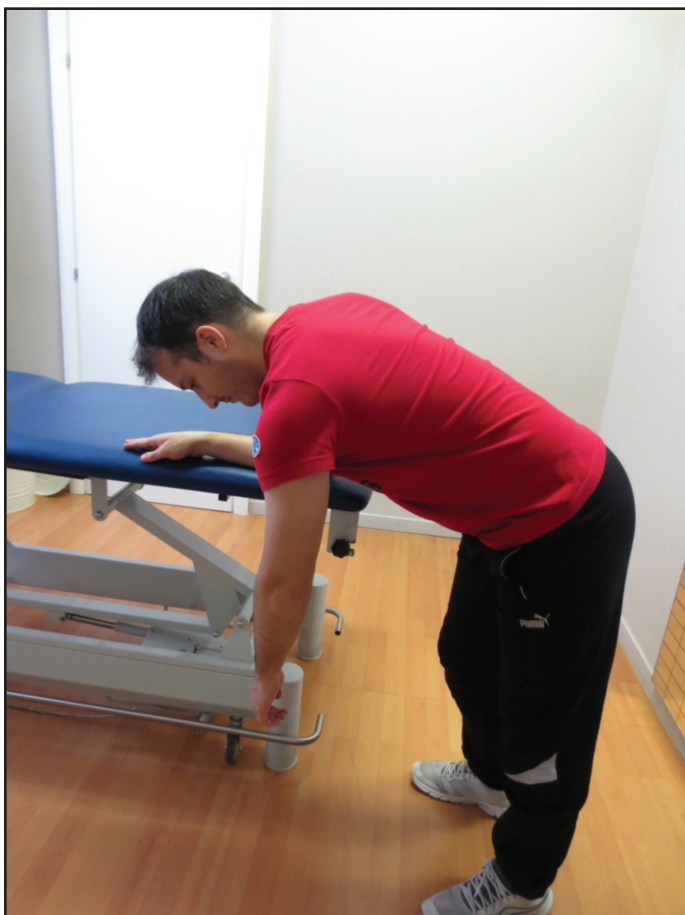


Figure 2. *Pedulum exercise with the supporting arm on a table.*

Aquatic therapy (the use of the water for rehabilitation purposes), can be safely introduced once the stitches have been removed and the surgery wound has healed completely. This rehabilitative technique provides a supportive medium, facilitates ROM, and is a method to light initiate resistance training.¹³⁰⁻¹³² Moreover, various exercises performed in water demonstrate less rotator cuff electromyographic activation than when performed on the land,¹³³ aquatic therapy offers a safe environment to perform movements without compromising the healing process of the repair site.

During this phase, attention should be also placed on a good postural awareness and control of the spine and of the scapula by activation of the scapular musculature. Scapular retractions and depressions are appropriate exercises to activate the shoulder girdle musculature with minimal rotator cuff recruitment.¹³⁴ To improve muscle activation awareness, it is advisable to use an electromyographic biofeedback. Patient education is of the utmost impor-

tance for this phase of the rehabilitation program, as the patient may need to carry out the prescribed exercises at home with minimal supervision of the therapist.

Criteria to progress to the next phase are: minimal discomfort when the shoulder is unsupported, pain-free passive flexion to 130° , pain-free passive internal and external rotation to 50° in the scapular plane.

Phase II

The patient may be ready for this phase at 3-4 weeks post-surgery although it may be delayed depending on the quality and size of the repair.¹³⁵ During this phase the healing process is increasing the tensile strength of the repair site which is now able to withstand higher mechanical loads.¹³⁶ Exercises during this phase are performed in order to attain full pain-free ROM, improve neuromuscular control, restore



Figure 3. *Low rows. The patient is standing with one hand on the edge of a table and pushes backwards retracting and depressing the scapula.*

normal patterns of muscle contraction and to return to normal ADLs. The use of pulleys, canes, and active assisted ROM (AAROM) are indicated at this point to enhance movement and recover full ROM. Stretching of the pectoralis minor muscle if it restricts upward rotation of the scapula is also advisable. Submaximal isometric contractions in all planes and at multiple angles can be initiated at the stage. Activation of the scapulothoracic stabilizers should still be a major focus as it allows neuromuscular control and full pain-free ROM. Attention should be placed to the scapular retractors (rhomboids and medium trapezius muscles), scapular protractors (serratus anterior muscle) and scapular depressors (lower trapezius muscle) which are enhanced with low rows (Figure 3).

Excess upper trapezius (UT) muscle activity with decreased activation of the lower trapezius (LT) muscle has been proposed to contribute to poor posture, muscle imbalances, and several shoulder pathologies.^{137,138} Therefore, it is important to assess and address the LT/UT and middle trapezius (MT) muscle/UT activity ratio.¹³⁹ Exercises that enhance the LT/UT and MT/UT activity ratios are side-lying external rotation with a pillow between the body and the arm¹⁴⁰ (Figures 4 A-B), side-lying forward flexion

and prone horizontal abduction with the shoulder in external rotation.¹³⁹

The serratus anterior can be activated in supine by scapular protraction in 90° of shoulder flexion (Figures 5 A-B).

Scaption (scapular plane elevation) can be introduced at this stage to initiate recruitment of the supraspinatus muscle. Initially, it is advisable to perform this exercise with the elbow bent at 90° to reduce excessive stress to the repair site by using a shortened lever arm (Figures 6 A-B). Next, this exercise can be progressed to the “full can” exercise (Figures 7 A-B), which is known to demonstrate high activation of the supraspinatus,^{17,33} minimizing the chance of subacromial impingement.¹⁴¹ Due to the simultaneous activation of multiple muscles, it has been suggested that scaption (full-can) exercises be implemented when preparing a patient to perform tasks that require open chain elevation beyond the shoulder level.¹⁴²

Open chain proprioceptive activities can be initiated during this stage. Examples include joint positioning and mirror repositioning for flexion.¹⁴³ In supine, the noninvolved shoulder is positioned at a certain angle of flexion and then the patient tries to mirror

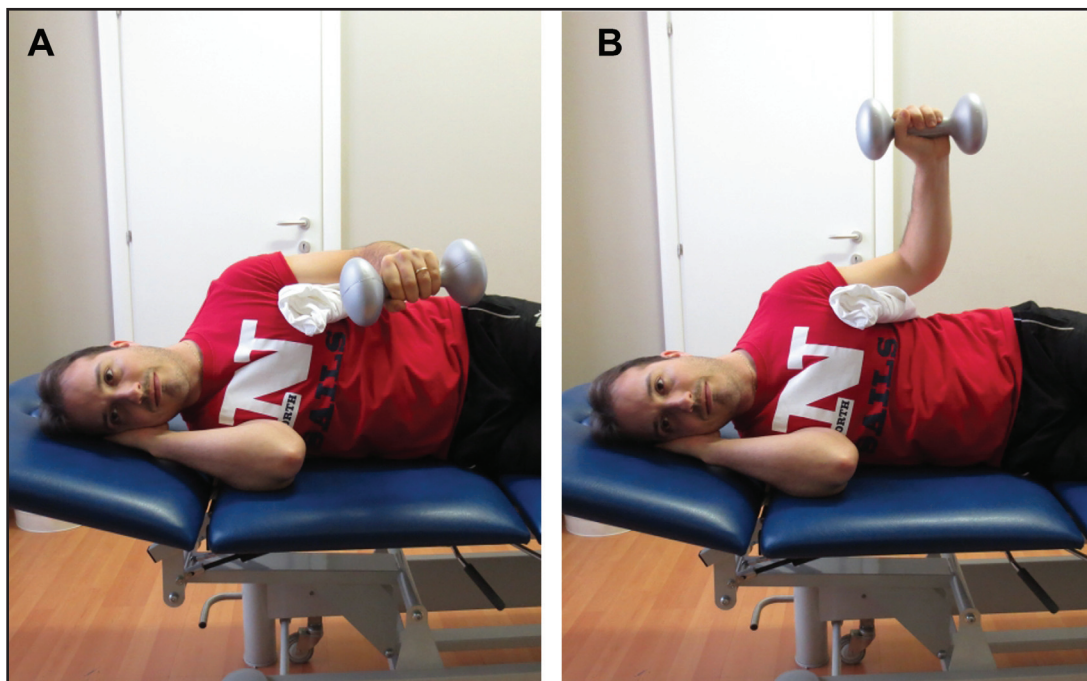


Figure 4 A-B. External rotation in side-lying. Beginning position (A) and ending position (B).

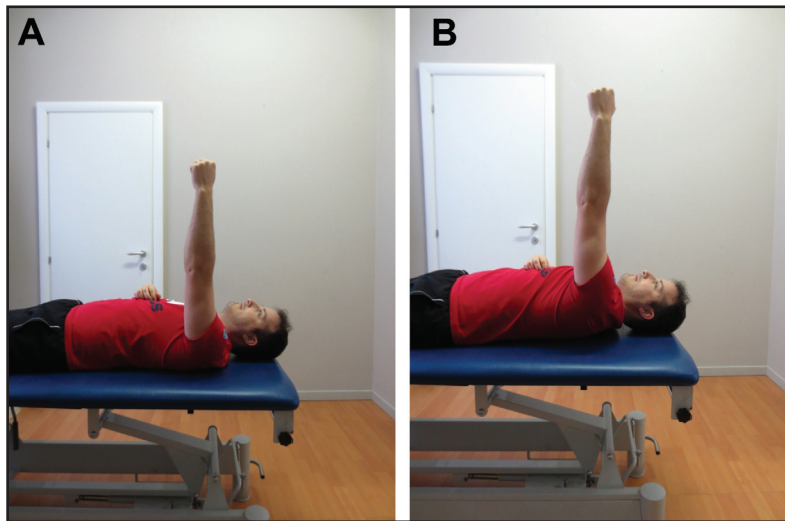


Figure 5 A-B. Activation of serratus anterior in supine by scapular protraction. Initial position (A) and ending position (B).

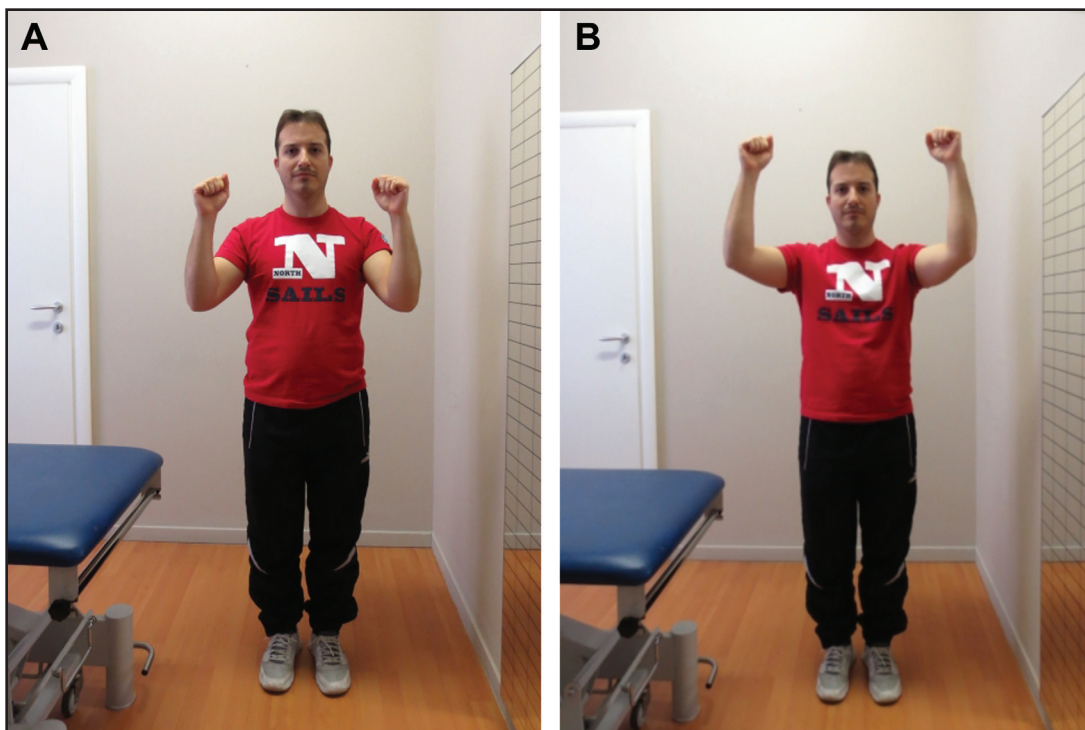


Figure 6 A-B. Scapular plane (scaption) exercise with elbows bent at 90°. Initial (A) and final (B) positions.

the same angle with the involved shoulder with and then without visual clue (Figures 8 A-B). This exercise is also important for monitoring the activity of the UT during elevation tasks and avoiding the shoulder shrug position.

Criteria to progress to the next phase are: full pain-free ROM, negative impingement tests and no scapular dyskinesia during both static positions and active scaption movements.

Phase III

Phase three generally starts at 6-8 weeks post-surgery, at which time the remodeling phase is nearly complete and soft tissues are reasonably well healed, requiring less protection that during the earlier stages. Exercises during this phase are progressed and directed towards aims such as: improving strength and endurance of the rotator cuff and shoulder girdle muscles.¹⁴⁴ Shoulder internal and external

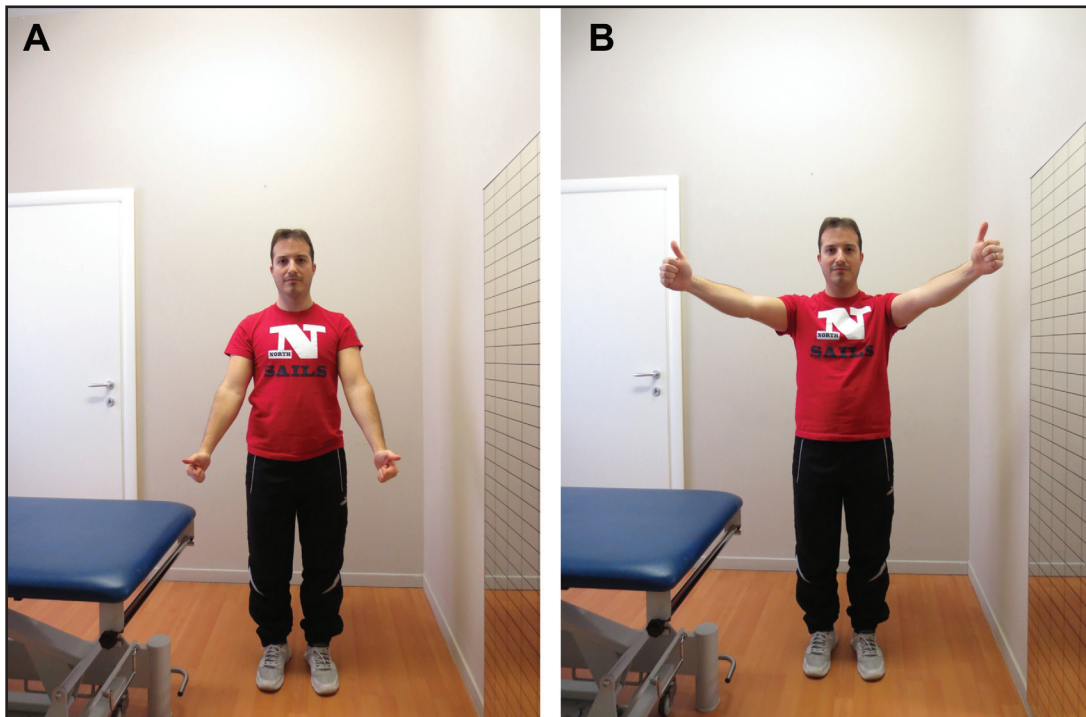


Figure 7 A-B. "Full can" exercise. The patient elevates the arms on the scapular plane from the side (A) to 90° of flexion (B), keeping the shoulder in external rotation (thumbs up).

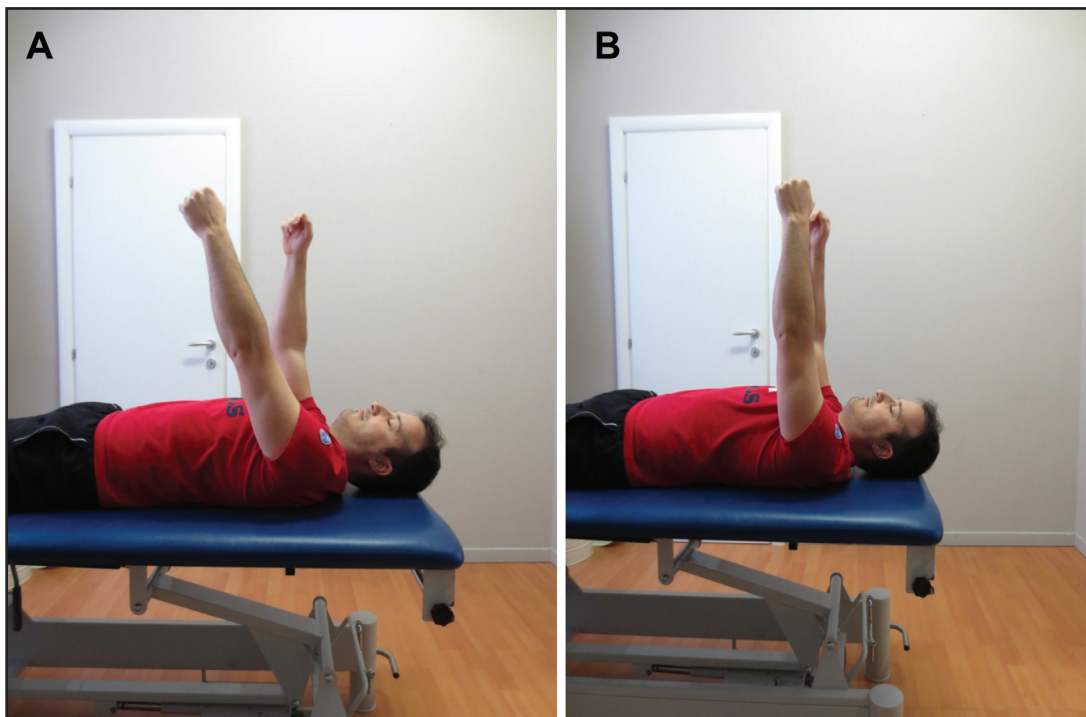


Figure 8 A-B. The patient positions the uninjured shoulder (right) at certain angle of flexion (A) and then mirrors the same angle with the involved shoulder (left) (B) with and then without visual input (queue).

rotator muscles are strengthened by motions utilizing graduated elastic bands with the arm in the scapular plane and below the shoulder height. To do so, it would be advisable to use a pillow or towel roll between the upper limb and the trunk as this configuration enlarges the sub-acromial space, reducing the risk of primary impingement (Figures 9 A-D).¹⁴⁵

Strengthening of the serratus anterior muscle continues with the dynamic hug exercise as illustrated by Decker et al.¹⁴⁶ This exercise is performed in standing, using elastic resistance and mimicking a hugging motion around a cylindrical object with the shoulder internally rotated to 45° (Figures 10 A-B). The muscle then is further strengthened via CKC

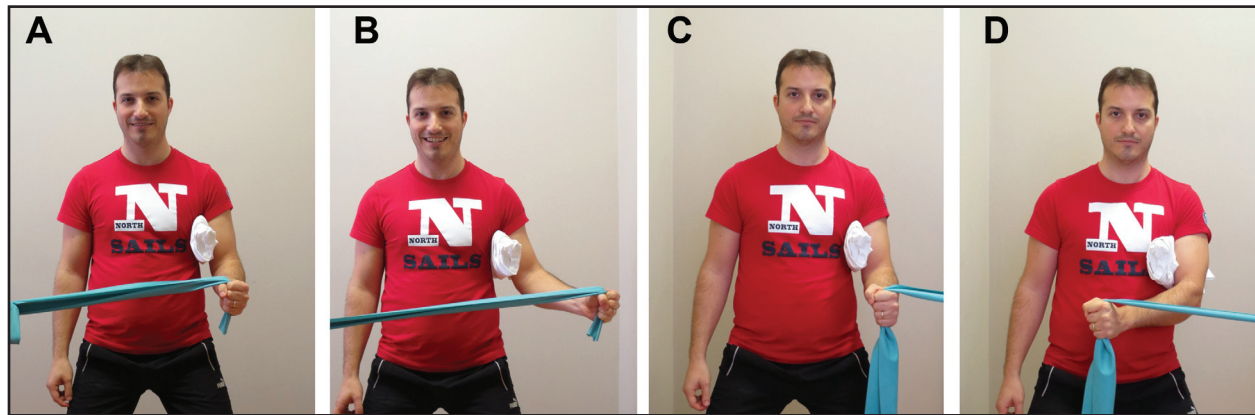


Figure 9 A-D. Strengthening of shoulder external and internal rotators with elastic band resistance, with a pillow between the trunk and the upper limb. Initial (A) and final (B) position for external rotators. Initial (C) and final (D) position for internal rotators.

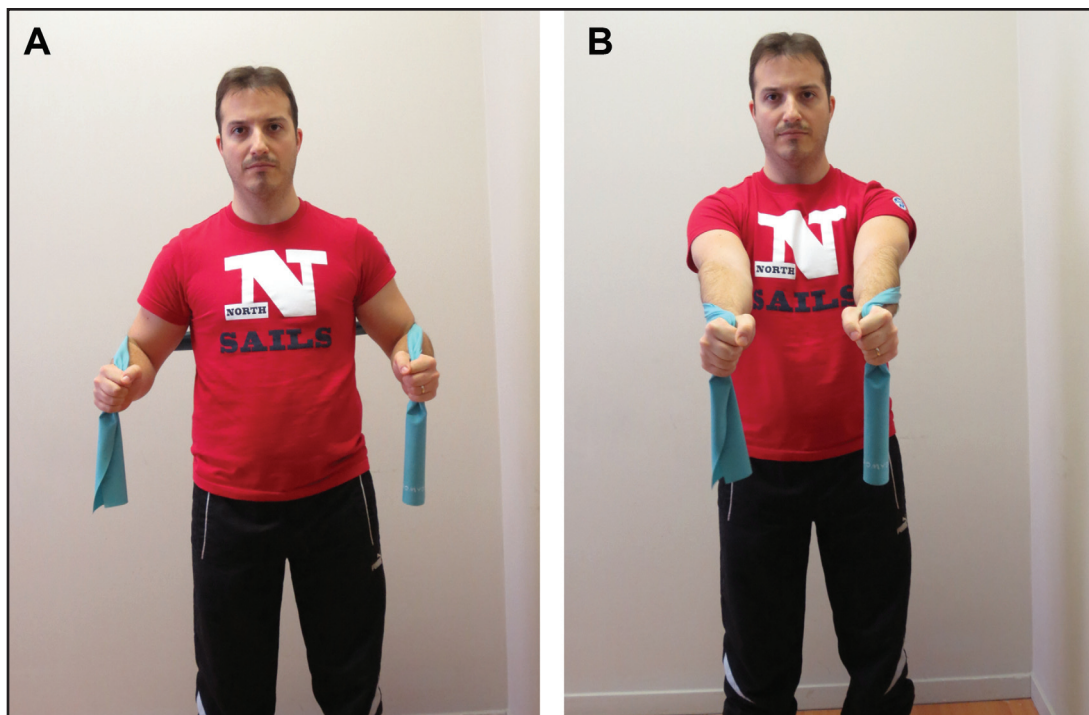


Figure 10 A-B. Dynamic hug exercise. With the resistance of an elastic band, the patients begins the exercise with the elbows flexed, shoulders abducted and internally rotated (A). Then the patient performs an imaginary arc, while extending the elbows, until maximum protraction is attained (B).

exercises using the “plus” position which is characterized by maximal scapular protraction, generating maximal activation of the muscle.^{143,146,147} An example is the pointer exercise with balance disc and oscillation device (Figure 11). As increasing upper extremity weight-bearing requires increasing should-



Figure 11. Pointer exercise with oscillating device and “plus” position on weight-bearing limb (left) for the serratus anterior muscle.

der musculature demand,¹⁴⁸ more advanced CKC stability exercises, such as: rhythmic stabilization in the quadruped position with weight shifts and perturbations or prone walkouts on a physioball, are

progressively introduced to improve neuromuscular control of the shoulder.

Trapezius and rhomboid muscles are also important and can be strengthened with elastic resistance (Figures 12 A-B).

To improve scapulothoracic muscular endurance, it is suggested to utilize exercises with low to moderate resistance, high repetitions (long-duration sets) and minimal rest between sets.¹⁴⁹ An upper ergometer may be also beneficial. However, in order to prevent sub-acromial impingement, it should be utilized in standing, with the axis of the ergometer below shoulder level.

Biceps and triceps brachii muscles may be addressed as needed at this time with conventional biceps curls and triceps extension using free weight (isotonic) or elastic resistance.

The therapist should guide the patient during the execution of all exercises in order to avoid substitution patterns (shoulder shrug sign) and encourage proper techniques.

To maximize force generation, utilize the entire kinetic chain during upper extremity movements,

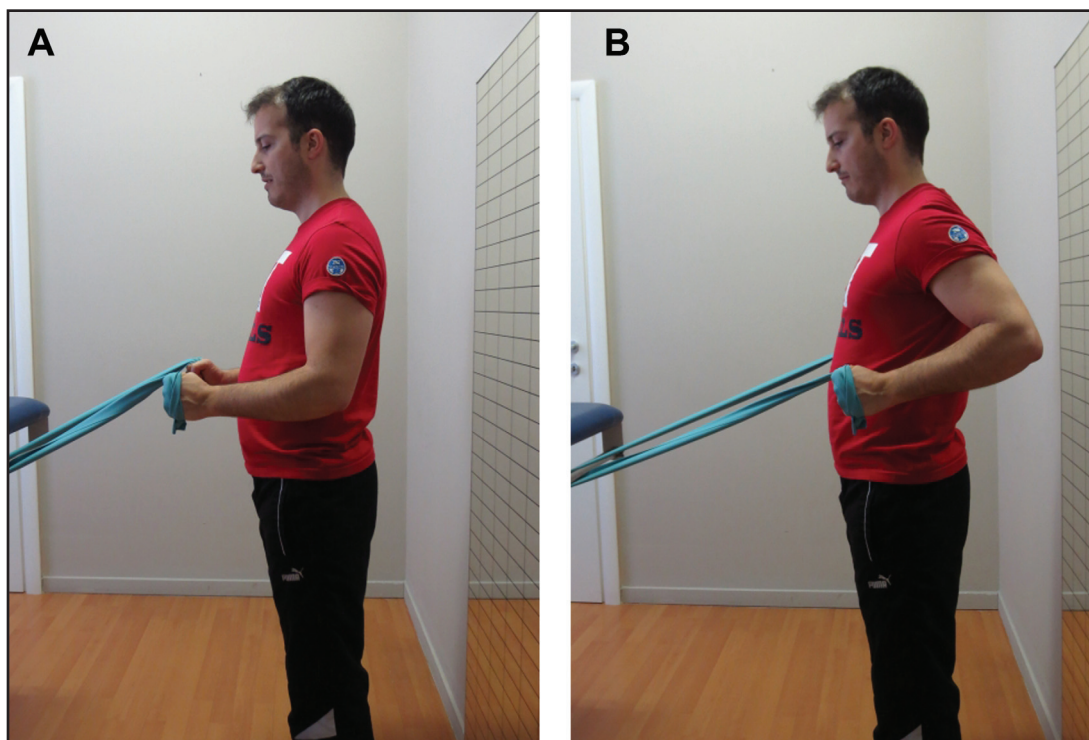


Figure 12 A-B. Elastic resistance for strengthening of trapezius and rhomboid muscles. Initial position (A) and final position (B).

and minimize joint loads, incorporation of a core stability-strengthening program is recommended. Although description of specific exercises and progression is beyond the scope of this clinical commentary, addressing the core is important, especially if the patient is an athlete who wishes to go back to sport activities.¹⁵⁰

Progression to the last phase is possible once the patient is pain-free with ADLs.

Phase IV

At about 12 weeks post-surgery, the healing process should be complete enough to allow the healed collagen to withstand increasing mechanical forces. This phase is a progression of Phase III, including more demanding strengthening exercises. Rotator cuff muscles are strengthened by using internal and external rotation with elastic resistance in more challenging positions such as: at 45° of shoulder abduction, initially, and at 90° of shoulder abduction later.

Advanced rhythmic stabilization training in open-kinetic-chain is accomplished by the use of an oscillating blade or device. The patient oscillates the blade vertically and horizontally while maintaining the shoulder in the scapular plane at about 90° of flexion (Figure 13). Progressively, the patient is



Figure 13. *Advanced rhythmic stabilization with oscillating blade.*

challenged outside of the scapular plane in more demanding positions, for example at 90° of abduction and 90° of external rotation, and eventually in sport-specific movements.

Plyometric training is also paramount and needs to be addressed in the late stages of Phase IV. Plyometrics employ the stretch-shortening cycle with the goals of stimulating the body's proprioceptors and increasing muscle recruitment over a minimal amount of time.¹⁵¹ Usually the patient starts by performing bilateral wall tosses and progresses to unilateral throws against a rebounder with progressively heavier weighted balls. Exercises should begin with positions below shoulder level and progress to overhead positions. An example of advanced plyometric exercise for the internal rotators is performed with the patient in supine with the arm in the 90/90 position, and the patient catches and immediately tosses back the weighted ball to the therapist. Such an exercise can be progressed to upright positions such as half-kneeling and standing.

Phase V (Return to sport)

After completing Phase IV, athletes should complete an interval sport program to safely return to competitive sport activities. Interval sport programs should be sport specific although there should be general exercise prescription focusing on cardiovascular endurance, scapulothoracic and rotator cuff muscle strengthening. Recurrences of injury to the rotator cuff should attempt to be minimized therefore, any reasons thought to facilitate PASTA lesions, such as anterior shoulder micro-instability should be addressed adequately. Once the athlete has completed the progressive return to sport program without complaint of pain or discomfort and has been cleared by the surgeon, return to competitive activity can be initiated.

Patients who are not athletes, should maintain the flexibility, endurance and strength levels achieved during Phase I-IV and may benefit from functional progression programs for activities specific for their function.

CONCLUSIONS

This clinical commentary provides an overview of PASTA lesions, presents options for management

of these lesions, analyzes the common treatment approaches utilized to date, and describes a rehabilitation program based on available scientific evidence.

Post-surgical rehabilitation of PASTA lesions should consider surgical findings, patient age, level of activity, and patient-related outcome goals. Moreover, understanding of soft tissue healing timing is paramount as it affects rehabilitation choices and provides the basic foundation for the progression of a rehabilitation program.

Therapeutic modalities and rehabilitative exercises are often based on clinical experience rather than scientific evidence, therefore, future research on PASTA lesions should be focused on providing scientific rationale for the use of therapeutic modalities and exercise programs as well as timelines for progression.

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