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PHYSICAL THERAPY MODALITIES AFTER ROTATOR CUFF REPAIR: A REVIEW ARTICLE

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Review about Physical Therapy Modalities after Rotator Cuff Repair.

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Introduction

The shoulder is a minimally constrained ball and socket joint, The shallow glenoid allows for a wide range of motion (ROM). Passive motion is determined by bony anatomy, ligamentous and capsular restraints, and musculotendinous (MT) structures that surround the shoulder. Shoulder motion can be grossly divided into scapulothoracic (ST) and glenohumeral (GH) motion. The scapula provides a stable base for muscle activation and load transfer (1,2).

The rotator cuff (RC) comprise of four small muscles working as a complex, rather than individually. The subscapularis (SSc) muscle is innervated by the subscapular nerve and originates on the scapula. It internally rotates the humerus and inserts on the lesser humeral tuberosity. The supraspinatus (SS) and infraspinatus (IS) are both innervated by the suprascapular nerve, originate in the scapula and insert on the greater tuberosity (GT). SS abducts the humeral head (HH) and acts as a HH depressor, while IS externally rotates and horizontally extends the humerus. The teres minor(TM) is innervated by the axillary nerve, originates on the scapula and inserts on the GT, externally rotating and extending the humerus (3). The RC both centralizes and approximates the HH within the glenoid (4).

The subacromial (SA) space lies underneath the acromion, the coracoid process, the acromioclavicular joint (ACJ) and the coracoacromial(CA) ligament. A bursa in SA space provides lubrication for RC (3).

RC disease is a painful condition with a multifactorial aetiology in which severe or chronic impingement of the RC tendons on the under-surface of the CA arch is often a significant factor (5). Rotator cuff tears (RCTs) are often the cause of debilitating shoulder pain, reduced shoulder function, and compromised joint mechanics (6) with clinical manifestations of shoulder stiffness, weakness, instability and roughness (7). Causes responsible for tear include anatomical factors, age related degeneration, tendon hypovascularity, genetic factors and traumatic injuries (5,8).

Factors associated with success include patient age, activity level, size , location and chronicity of the tear ,surgical timing , technique and fixation method, muscle fatty degeneration , smoking status , MT unit retraction , tendon and bone quality, osteoporosis, diabetes ,hypercholesterolemia , communication between the surgeon ,the physiotherapist (PT) and the patient , compliance with the PO rehabilitation and Pre-habilitation (1-3,9-14) .

Roddey et al (15) found in their recent study of the relationship among strength and mobility measures and self -report outcomes scores in persons after RCR surgery that population's self-reported function scores to be unexplained by impairment scores, suggesting that impairment scores fail to fully capture what patients rely on in evaluating their shoulder outcome and impairment measures are not enough.

John et al (16) in their large, multicenter prospective cohort study have shown that surgical treatment (ttt) may not be necessary for many individuals and believed that pain may not be the best indication for RCR. Weakness or loss of function may be a better indication for surgery than pain. It is known that asymptomatic tears may become symptomatic (17) and that in patients with bilateral RC tears where one is symptomatic and the other is not, the symptomatic tears is typically larger (18).This information would lead some surgeons to recommend surgery for all patients with RCTs (16). However, it is also known that progression can occur without the development of symptoms (17).One randomized controlled trial compared RCR with non-operative ttt in patients with RC tears (< 3cm)(19). In this study, the Constant scores at 12 months were significantly better in the surgery group; however, only 17% of patients randomized to their therapy group had failure and elected to have surgery. The indication for surgical ttt of RC tear is a documented PTT or FTT that has not responded to conservative ttt and produces symptoms that interfere with the patient's normal functioning (2,20). RC healing is not necessary for a good long-term functional outcome after RCR, although healing will likely result in improved strength, ROM and decreased pain (14).

kim et al (13) described the arthroscopic rotator cuff repair (ARCR); SA decompression was conducted to remove inflamed bursal tissue, and acromioplasty was performed. Then, the GT of the humerus was prepared to make a bleeding surface. Bioabsorbable anchors were inserted with a small stab incision. According to tear size and pattern, either single- or double-row (SR or DR) or suture bridge (SB) fixation was performed. In cases of small tears (<1cm) (the anteroposterior dimension was measured at the lateral edge of the torn cuff, and medial retraction was measured as the distance from the apex of the tear to the cuff insertion of the HH. The larger value of the 2 measurements was used as the tear size) many of them were repaired by the SR technique. In cases of medium tears (1-3 cm), many of them were repaired by the DR or SB technique, Suture passing into the tendon was done and knots were tied securely.

Healing of ruptured RC tendons occurs when the tendon is surgically repaired back to its footprint on the proximal humerus, Histological studies suggest that 3 phases of RC healing occur after surgical repair, an inflammatory phase (1st week), a proliferative or repair phase (2-3week), and a remodeling phase (2-4week) (2). The
function of the SA bursa in healing include the gliding between two layers of tissue, the blood supply to the cuff tendons and the contribution of cells and vessels after surgical repair (21).

Advances in arthroscopic shoulder surgery and rehabilitation have placed increased emphasis on different land-based exercise programs, including adjunctive aquatic exercise programs. Therefore, in this review we will evaluate the effectiveness of different land-based exercise programs and aquatic exercise programs including factors affecting the rehabilitation, immobilization versus early ROM, unsupervised versus supervised PT, rehabilitation goals, protection of repaired tendon ,electrotherapy (HWD,NMES,US) , cryotherapy, aquatherapy, passive motion, joint mobilization, strengthening and return to sport.

Rehabilitation

Factors affecting the rehabilitation

Factors affecting the rehabilitation (1,2,9) are :-

The surgical approach, patients who have deltoid muscle detachment, as in open RCR, avoid active deltoid contractions for 6-8wk. With mini-open RCR in which the deltoid is split vertically, Allow mild deltoid isometric contractions and return to previous activity 1 month earlier than open repair. With ARCR there is significantly less PO pain . Patients who underwent mini-open repair.

The size of the tear , for small tears, the rehabilitation progresses slightly quicker than for larger tears.The amount of retraction, with the more retracted tendon requiring a slower rehabilitation (by delaying PROM 4weeks, AROM 6-8weeks (10).

Tendon, muscle and bone quality, the quality of muscle tissue can be assessed on preoperative magnetic resonance imaging (MRI) with assessment of muscle atrophy and fatty infiltration.Rehabilitation for the patient with adequate tissue would be a slightly more aggressive .

The fixation method, SR repair is more vulnerable to tendon-bone gap formation with early PT than is DR repair. DR repair has better fixation strength.

The location of tear, Tears that extend to involve posterior cuff structures (IS and TM) require greater protection and restriction . Rehabilitation after SSc repair should restrict the ER until early tissue healing has occurred, thus gradually restoring motion. Also, resisted IR should be limited for 4-6wk.

The type of tear, classified based on shape and amount of retraction. The most common types of RC tear are crescent shaped, U-shaped, and L-shaped. RCTs tend to propagate; thus, crescent-shaped tears progress to U-shaped tears and U-shaped tears may progress to L-shaped tears. Furthermore, tears tend to retract proximally, which makes it more difficult for the surgeon to repair due to available tissue and tissue tension thus treated more cautiously.

The mechanism of failure of the RC tear and The timing of the repair Similarly, when other procedures, such as a superior labrum anterior posterior (SLAP) repair or capsular plication, are performed concomitantly with the RCR, there is a greater tendency toward PO stiffness requiring more aggressive initial PROM.

The surrounding tissue quality, for a RC tear confined to the SS, it is important that the PT be made aware of the SSc and IS/TM tissue quality thus preventing or reducing the probability of the isolated SS tear propagating anterior or posterior. If the surrounding tissue quality is fair to poor, then the PT should be cautious.

The patient's characteristics, such as age, level of activity, diabetes mellitus and general health, lifestyle habits, work situation, recreational activities, patient interaction (3) and arm dominance(dominant arms require greater ROM and strength).

Access to care and the surgeon's philosophical approach to rehabilitation, patients who are treated by a skilled PT do significantly better than patients who are treated by a home exercise program (HEP).Other factors include histological healing time lines and the attainment of specific clinical goals.

Immobilization versus early ROM

The timing for the initiation of PO motion following ARCR remains controversial (22). The aggressive rehabilitation protocol may entail higher risks of RC un-healing and a higher re-tear rate than the traditional protocol (10) ,the idea of delaying rehabilitation and reducing stress at the repair site appears attractive (23). The rationale behind a delayed rehabilitation program stems from concerns that early repair site micro motion and gap formation may negatively affect tendon healing (24) and Tendon immobilization improves tendon-to-bone healing (9). The benefits of immobilization for tendon healing may be more important for older patients or in shoulders with larger cuff tears as it did not appear to lead to greater risks of shoulder stiffness. Many surgeons choose to protect the repairs during the vulnerable 3 month PO. Delaying rehabilitation may reduce the costs of PT visits in the early PO period (24).

Several authors have examined the influence of delayed rehabilitation after ARCR on PO motion reporting PO stiffness with delayed motion for RCRs is not a concern and that these patients will eventually regain their mobility and ROM (13,23), indicated that avoiding early motion may have potential benefits in an effort to protect repaired tendons (14). Several animal model studies have demonstrated that immobilization reduces tendon load-to-failure/stiffness and allows better tendon to bone healing. Over-activity may lead to inflammation and increase the production of scar tissue with lower biomechanical loads (23,25-27). ARCR may allow for a more conservative approach to mobilization to maximize RC healing (28).

Peltz et al (25) performed study evaluating the effect of increased post-immobilization activity after the shortest period of immobilization previously resulted in beneficial changes to the healing insertion site. They concluded that after a short period of 2weeks immobilization, an increased level of activity is detrimental to both tendon mechanical properties and shoulder joint mechanics due to increased scar production. It is possible that increased loading following a longer period of immobilization, after which the tissue at the repair site is well-organized, may produce more of the desired tendon tissue rather than scar, resulting in superior mechanical properties (25).

Parsons and colleagues (23) retrospectively reviewed patients who underwent ARCR for a FTT followed by 6 weeks of sling immobilization without therapy. At the 12-month follow-up, they found no significant difference in forward elevation, IR or ER between the patients categorized as non-stiff or stiff (<100^{O} passive forward elevation and <30^{O} ER according to their initial PO ROM at 6-8wks of follow-up. These results support the notion that special treatment beyond formal therapy may not be necessary in a patient with early restricted PROM after ARC. They found a 56%retear rate especially in larger tears. Among the stiff patients, 70% of the tendons were intact, compared with 36% for the non-stiff patients. This difference approached, but did not reach, statistical significance. Tears exceeding 3 cm had a statistically higher incidence of re tear at the 1-year follow-up .The authors concluded that, even in patients who developed early stiffness after conservative rehabilitation, long-term stiffness was unlikely with delayed rehabilitation and no patient required a release for recalcitrant stiffness, despite these more conservative expectations for ROM suggesting that longer immobilization periods (2-4weeks) often recommended to minimize stress placed on the repaired tissues to facilitate early tissue healing, protect surgical repairs and may not increase the incidence of PO stiffness, Therefore, this may suggest that stiffness at 6 weeks after ARCR should not be a cause for alarm.

Huberty and colleagues (29) also looked at patients treated with sling immobilization and only ER for the first 6 weeks after an ARCR. They found only 5% of patients became dissatisfied with their result due to stiffness, If a patient had one identifiable risk factor, the incidence of stiffness was 13%. All unsatisfied patients elected to undergo arthroscopic release and all were satisfied after release. Koo et al (30) followed-up the prior study by adding a table slide exercise to the at-risk group identified in the prior study. With the addition of the one exercise, the incidence of stiffness was reduced to 0%.

Cuff and colleagues (31) in their Prospective, randomized study that has been performed comparing delayed versus early passive motion after RCR. They determined that there was no difference in final ROM or functional outcome scores between groups at one year PO and reported lower re-tear rates in the delayed rehabilitation groups, compared with the early motion groups although none of these differences were statistically significant.

Based on these results, slower rehabilitation does not appear to affect long-term stiffness in general. There are some groups of patients that might benefit from earlier motion in which introduction of one table slide exercise may limit the development of stiffness. While not statistically significant, there does appear to be a trend that delayed motion may improve healing rates after RCR. Consequently, in patients at risk for limited tendon healing (i.e. large tears, older patients, poor muscle quality), slower rehabilitation can be initiated to improve healing rates with limited risk of development of stiffness.

Recent basic science investigations have suggested that the inflammatory response is higher after open RCR, and PROM may actually increase PO adhesions (28) .

Denard et al (28) in their systematic review of articles related to PO stiffness following ARCR showed that a 6-week immobilization protocol slightly increases resistant stiffness compared to patients treated with an immediate PROM protocol or a modified protocol that included early closed chain passive overhead stretching for patients who were in the at-risk group for PO stiffness, which can be successfully managed with arthroscopic capsular release (ACR). they believed that stiffness that can be successfully treated with a subsequent ACR far outweighs the negative consequences of a recurrent RC tear. They suggested there may be a positive relationship between stiffness and RC healing with stiffness being considered a complication and recurrent RC tear a failure .

In addition to the role in the development of stiffness, immobilization after RCR may lead to increased healing potential. Thus ,they reported that the ideal rehabilitation protocol to prevent stiffness and encourage healing after RCR includes an initial period of immobilization (28) .

Gimbel et al (32) reported that immobilization of the shoulder improved tendon-to-bone healing in the rat model
because it allowed for an increase in the organization of collagen fibers, which led to an increase in mechanical properties.

Koh et al. concluded that 8 weeks of immobilization did not yield a higher rate of healing of medium-sized RCTs compared with 4 weeks (33).

Kim et al (13) in their prospective, randomized comparative trial to verify whether early shoulder PROM affects ROM, functional outcome, and cuff healing after ARCR of small to medium-sized RCT, they demonstrated that early PROM had no advantage (no statistical difference in the healing rate between the 2 groups at the 1-year follow-up) for either early gain of ROM or clinical outcome. That is, delayed rehabilitation after ARCR did not result in PO stiffness and poor clinical outcome compared with early motion. This implies that early PROM after ARCR of small to medium sized RC tears does not seem to guarantee the early gain of shoulder ROM, pain relief, or functional recovery and does not seem to negatively affect cuff healing so not mandatory.

The literature shows that early aggressive rehabilitation protocols may result in a slightly higher incidence of re-tear compared with more conservative protocols. The benefits of early aggressive therapy protocols seen in the early PO period on pain relief and ROM, however, are not observed with longer term follow up. The risk, therefore, may outweigh the benefits of such protocols in the majority of cases supporting the use of a slower rehabilitation protocol (13).

On the other hand, several investigators reported the importance of early PROM after RCR surgeries as prolonged immobilization may delay recovery and adversely affect normal tissues (34) and the effect of reducing pain within 3 to 4 months and prevent PO stiffness after surgery was demonstrated in an aggressive early PROM protocol (10) . Risk factors for PO stiffness include (2,28,14) small tear size; worker’s compensation; age <50; calcific tendinitis; adhesive capsulitis and concomitant labral repair (28).PO stiffness has been one of the most dreaded complications after open RCR, and as a result, immediate PROM protocols were advised, Early PROM exercises of the shoulder both prevent adhesions and protect the repair (20).

Recent data suggest that PROM early (aggressive rehabilitation in which PROM can be started 1 day PO, and AROM may follow several days later (10)) is an ideal rehabilitation program that best allows for tendon to bone healing (1,13) while preventing shoulder stiffness (1,10,13) and early recovery of shoulder ROM and function (10). There is strong evidence that early initiation of rehabilitation does not adversely affect outcome in terms of patient reported outcome of pain and disability in the short (3 months), mid (6 months) or long term (≥12 months) (35).

Huang et al (10) in a meta-analysis included 6 RCTs that compared the effects of aggressive rehabilitation protocols and traditional protocols in patients after RCR found that the differences between the two protocols were nearly significant in that the aggressive rehabilitation protocol first, was superior to the traditional protocol in the outcomes of overall ROM at 6 months and 1 year after repair, and second, led to greater improvement in shoulder function.

Ellenbecker et al (26) in their retrospective chart review of shoulder ROM and rotational strength 6 and 12 weeks following RCR using a mini open deltoid splitting technique described an exercise therapy program consisting of active AAROM, AROM, and muscle strengthening exercises; at 12 weeks PO , the final outcomes in motion were a mean AROM deficit of 5° to 7° in abduction, IR, ER, and full return of forward flexion. The final outcomes in isokinetic strength were a mean deficit of 5% to 7 % in the ER and a mean improvement of 6% to 11% in the IR.They concluded that the application of early ROM and progressive strengthening following mini-open RCR allows for the successful return of ROM and strength 12 weeks PO.

Lee et al (12) In their randomized controlled trial comparing ROM and healing rates between two early exercise programs; one with unrestricted PROM exercises, and another with limited PROM exercises after arthroscopic SR repair for FTT of RC ,both programs consisted of manual PROM, CPM, AROM, and strengthening exercises. At 6 months, 12 months and 2 years PO, there was no significant ROM difference between these two groups. It can be easily supposed that the aggressive early passive rehabilitation protocol put more stress on the repaired RC than the limited early passive rehabilitation protocol. Pain, ROM, muscle strength, and function all significantly improved after ARCR, regardless of early PO rehabilitation protocols. However, aggressive early PROM may increase the possibility of anatomic failure at the repaired cuff.

A gentle rehabilitation with limits in ROM and exercise times after ARCR would be better for tendon healing without taking any substantial risks (12). Early, safe motion allow optimal tendon healing, yet with minimal stress applied to the repair (9).

Duzgun et al (27) compared the effects of the slow and accelerated protocols on pain and functional activity level after ARCR they concluded that an accelerated protocol of immediate PROM seems to decrease pain in the short term than immobilization of the shoulder after RCR , prevent the negative effects of immobilization and support rapid reintegration to daily living activities (ADLs).

The same authors (22) conducted another study in 2014 to investigate the effects of the early initiation of P/AROM exercises following ARCR found that AROM for all measurements improved across weeks, there were no differences between groups, with the exception of active total elevation which was greater at all time point measurements in the ACCEL group, they concluded that the early initiation of passive and gentle controlled AROM exercise following RCRs does not appear to affect ROM (i.e. decrease ROM or causing stiffness) in the 1st 6 ms PO.

Littlewood et al (35) in their systematic review evaluating the effectiveness of rehabilitation programmes following surgical repair of the RC suggested that concern about early initiation of rehabilitation and introduction of functional load, in the form of patient-directed active exercise, following surgical repair of the RC might not be warranted in terms of adverse patient-reported outcome. A marginal increase in tendon re-tear is evident but not statistically significant.

Keener et al (24) in their prospective randomized trial of immobilization compared with early motion found that initiation of early ROM PO did not alter the outcome or likelihood of tendon healing. There were no differences in final shoulder function between patients treated with either an early or delayed motion protocol. This study also established that, for small and medium cuff repairs, most outcome scores plateau after 6-12 months, although early PROM appears to have had no detrimental effect on healing in these studies, aggressive stretching should be avoided. Either early passive motion or a period of early immobilization is equally safe and effective but not applicable to all after surgical RCR.

Unsupervised (HEP) vs. Supervised PT

One potential advantage of the PT supervised exercise programs is the professional guidance may motivate patients, ensure the exercises are performed correctly and progressed according to the patient's individualized improvement. Patients who are involved in supervised therapy may become more invested in their rehabilitation by receiving proper and ongoing feedback (36).

In a qualitative study of patients with neck pain (36), patients reported that having someone measure their outcomes was a significant motivator to keep them on track with their home exercises. This suggests that the potential benefit of supervised exercise is the monitoring. However, depending how home programs are delivered the effect of monitoring may or may not be embedded.

A home-based program may imply that no one is overseeing what is being done by the patients; whereas in a clinic-based program, at least theoretically, a therapist or an instructor is monitored to make sure that the exercises are performed correctly. On the other hand, a home-based exercise program can be somewhat supervised if patients are rechecking with their therapist on a regular basis. Advantages of a home-based exercise are that it is less resource intensive and saving time and cost (36).

Hayes et al (37) compared 2 different forms of rehabilitation for subjects with full thickness RCR a standard 6 mo unsupervised HEP (Phase 1elbow ROM, grip, scapular retraction and pendulum. Phase 2,8 days PO, AA shoulder flexion and ER ; and isometric shoulder motions(3-5x/d). Phase 3, 6weeks PO, active shoulder flexion, horizontal flexion and ER; AA shoulder flexion, extension, ER and hand behind back; theraband-resistive all shoulder motions) to individualized, supervised PT among 58 adults comparing ROM, muscle force, and functional outcomes, Both programs consisted of AA, A, and strengthening exercises.

At 24 weeks follow-up, the outcomes in motion were a mean improvement of 3°, 12°, and 8°, for flexion, abduction, and ER respectively, determined that subjects allocated to individualized PT ttt were no better than subjects allocated to a standard HEP in terms of long-term shoulder joint ROM, muscle force, or functional outcome . Both groups demonstrated outcomes that were consistent with near full passive shoulder ROM and muscle force capacity, and a markedly improved overall shoulder status. Several AAROM exercises that the patient can perform at home during all phases include using the normal arm to assist and elevate the operative extremity to bring to the top of the head . Then the elbows are extended to increase flexion . This can also be performed with the hand behind the head to increase ER (37).

Baumgarten et al (38) in their systematic review of RCR rehabilitation, they concluded that there is no proof of an advantage of a supervised, individualized rehabilitation protocol compared to an unsupervised, standardized home program.

Goals of the rehabilitation

The emphasis of the PO rehabilitation is to 1-Maintain the integrity of the repair to allow healing of the repaired RC (9) without overstress because immediately following the repair as growth factors peak 2-3 week, culminating in the weak fibrin clot being replaced by loosely organized type III collagen callus, neither of which can withstand physiologic loads (1,2). 2-Educate the patient regarding protection of the repair site and the delayed nature of the healing process (9). 3-Prevent the deleterious effects of pain (9,39,40), effusion (1,2), and muscle inhibition (13,41). 4-gradually increase PROM (9,39,40).5-Prevent stiffness (9).6-regain strength (1,2,39,40).7- Initiate voluntary control of the RC (1,2) and 8-Return the patient back to functional activities (39,40) .

Protection

Abduction pillow shoulder immobilizer (45°) is used after RCR for 4-6 weeks according to tear size and fixation stability to enhance regional blood flow by preventing the “wringing out” effect in blood vessels to the tendon (known that the hypovascular region of the RC is about 1.5 cm from its insertion on the GT) and Reduce the distance between the origin and the insertion of the MT unit so that passive tension on the repair site will be decreased (1,2,41) thus protect the surgery site. Strain was lowest in the scapular plane compared to the sagittal plane from 0-45^o abduction (9).The patient may come out of the sling 3-4 times (after each meal) during the day to perform the passive exercises and during a shower. The sing should be used in the precarious situations, such as when outside the home or work environment, and to provide comfort (26). No specific objective criteria were used to monitor and direct sling use (26).

Zuckerman et al (42) in their biomechanical study of the effect of arm position and capsular release on RCR of small and large tears of the RC identified some of the factors that are important in determining the tension on the repair (PO positioning),For small tear the SS loads increased at 15^o abduction and were greatest when the arm was lowered to 0 abduction . In this position the load did not exceeds 50% of failure load except when the humerus was also flexed and lateral rotated.

When a capsular release had been performed there did not appear to be a position at which a repair was at risk, for large tear a SS loads increase significantly and followed a pattern similar to that shown after a small tears. Flexion consistently generated the greatest loads and extension consistently generates the lowest. capsular release significantly decreased the load generated but, even following capsular release, flexion produce high loads which occasionally approached failure levels, the bone was the weakest link in the repair, at least when healthy tendon tissue was available .bony failure occurred at the anterior part of the SS repair; loss of fixation of the IS tendon to bone did not occur. These observations indicate that the greatest loads are sustained by SS tendon anteriorly. Repair should be performed at or near the abduction to be held PO. If simple sling immobilization is planned, the repair should be performed at or near zero abduction. By contrast, if PO abduction splinting is to be used, it need only be at a slightly greater angle of abduction than was necessary to perform the repair (42).

Position of abduction has a much more important influence upon repair tension than rotation or flexion/extension but, if the arm is positioned in zero abduction, flexion should be avoided. Release of the capsular attachment at the glenoid rim significantly reduces the tension on the SS repair, especially for large defects .capsular release allows positioning at zero abduction when repairs are performed at 30^o abduction.

PO program of passive movements should avoid flexion with the arm at 0^O abduction. Flexion from an abducted position is to be preferred, since abduction of 15 or 30^O consistently negated the effect of flexion. Sleeping (in sling and brace), usually more comfortable for the patient during the first few weeks PO to sleep in a recliner with a pillow underneath the operative extremity while wearing the abduction sling (42).Pillow or towel roll may be used under the arm to help alleviate passive tension across the RC (1,2).

Electrotherapy

Electrical current flow appears to be integral to the healing of collagen containing tissue, i.e. tendons. Accordingly, it is reasonable to hypothesize that externally applied electrical fields should be able to enhance healing, especially in conditions that have resisted more standard treatments. Presently, of the three major types of electrical stimulation, i.e., direct, and capacitive and inductive coupling, there is a growing trend toward utilization of the latter because of its efficacy and greater margin of safety. There is increasing evidence that electrical stimulation exerts its influence via effects at the cellular and/or molecular levels within the tissue (43).

Ultrasound

Continuous US applied at 1.5 to 2.0 W/cm2 for 1 minute to the inferior Axillary fold of the joint capsule, was used throughout the 6 weeks of intervention to increase tissue extensibility (44). There are variable reports (44-46) of the heating and mechanical effects as well as effectiveness of US in the literature.

One report (47) in 2001 reported that there is not enough evidence to support the clinical use of US for management of pain and soft tissue injury. Another study (48) comparing US and knee ligament stretching with a placebo US and stretching of the knee on volunteers who were healthy demonstrated only 13% change between conditions. The researchers concluded that stretching with US might not increase the extensibility of the tissue more than stretching without US.

Additionally, US devices from different manufacturers may not have the same calibration. Due to those differences, the effects on the human tissue among devices may not be equivalent (49).Another source (50)reported that the heating effect appears to be greater in poorly vascularized structures such as ligamentous tissue and decreased in highly vascularized structures such as muscle. The structure targeted was the inferior joint capsule, which is a ligamentous structure that also has a small area; therefore, the application time was limited to just 1 minute to avoid overheating the structure (40).

Although commonly used to manage RCT, the efficacy US in the PO setting remains controversial. There is a paucity of well-controlled clinical trials that have evaluated their role in patients with RCT.This modality may have an effect on pain and limited motion, but their impact on the underlying tear and repair is not known (1).

H-Wave electro stimulation device

HWD (3) (1-60HZ, Channel A electrode placement: Superior pad was placed at the superior angle of the scapula; overlapping the middle fibers of the Trapezius and origin of the SS. Inferior pad was placed just superior to the Deltoid Tuberosity on the Humerus bone. Channel B electrode placement: Anterior and posterior pads were placed at the beginning and end of the suture line of the open reduction surgery) when used early PO induced fluid shifts, increased blood flow dependent on NO and potentially initiated the angiogenesis process. Inactivity of the shoulder in some will result in soft tissue fibrosis and joint contracture following RCR.

while PT was not allowed for most patients to begin until 8 weeks PO, it was noted that the patients receiving HWDS compared HWDSHAM, began to move in a micro-way earlier under the sling. These findings in this preliminary investigation suggest but do not mandate that HWDS compared to PLACEBO in PO ttt of RCR induces a significant and robust increase in ROM, function and possibly strength, which will ultimately lead to a faster healthier recovery. Emerging evidence from both animal and human studies indicate that nitric oxide (NO) plays a key role in wound repair (3).

The fact that animal research has shown that repetitive HWDS induces significant angiogenesis compared to single or intermittent HWDS suggest that this finding may induce healing in tissue tears. Muscular contraction or shear-wall stress is the best known factor for the intrinsic production of angiogenesis. Interestingly, by stimulating slow twitch myofibers, with associated mitochondria activity, a larger and denser network of angiogenesis will be formed while the use of arthroscopic procedures for most knee conditions yields relatively mild and controlled pain, ARCR induces more significant pain for the patient during the recovery phase, and hence remains a great challenge (3).

A total of 6535 participants were included in the meta-analysis (51-56). The findings indicate a moderate to strong effect of the H-Wave device in providing pain relief, reducing the requirement for pain medication and increasing function. The most robust effect was observed for improved function, suggesting that the H-Wave device may facilitate a quicker return to work and other related daily activities (56).

Pulsed electromagnetic field

Not only mechanical loading or growth factor signaling is important for healing processes. DNA activity concerning transcription and translation, as well as cell cycle mechanisms, plays a pivotal role. Those activities comprise proliferation, migration and apoptosis of cells. If these processes could be modulated, the healing of tendon tissue may be enhanced markedly. This modulation could prevent the occurrence of excessive strain by accelerating tendon healing. At the cellular level, healing involves the cells' detachment from and attachment to the matrix adjacent to the wound area, migration, and proliferation. PEMF (34)(10 min,33 HZ or 20 min,7.8 HZ- 0.25-3.14 micro T-6.3 mV/cm - 6mm from applicator) stimulates the communication mechanisms of cell and accelerate, among others, wound healing response. growth factor signaling, which is important for healing processes, can be influenced by PEMF.

Seeliger et al (34) investigated that certain low-frequency PEMF sequences influence in vitro wound healing of patellar tendon fibroblasts possibly via increasing the proliferation rate. The proliferation capacity of the cells probably plays a role in the secondary wound healing phase. After the migration phase that allows cells to go beyond the wound edges, cells have to proliferate in order to repopulate the wound area. tendon fibroblasts display 30% better wound area closure rates by low-frequency PEMF. PEMF is non-invasive, easy to handle, and has a short application time. PEMF enhances the regeneration potential of the destroyed tissue, especially the stimulation of new formation of connective tissue, something for which the vasodilatation and increased cell division are likely responsible (57). Furthermore, growth factor signalling, which is important for healing processes, can be influenced by low-frequency electromagnetic signals (34).

Chao et al (58) demonstrated an increased type I collagen expression in fibroblasts after exposure to pulsing electric fields. Earlier healing and improved stability following traumatic injuries to tendon are possible with PEMF stimulation (43).

Leonardo et al (59) in their randomized controlled study of PEMF after RCR (1.5Mt,75HZ,6-8hr/d for 6wk) found that application of PEMF after RCR provided significantly better clinical and functional outcomes in the short term (at 5 months) than those in patients undergoing RCR only, Improved ROM, reduced PO stiffness , inflammation, joint swelling, use of nonsteroidal anti-inflammatory drugs; improves pain control; accelerates recovery and allowed patients an earlier return to manual labor. Clinical and functional findings were comparable between the 2 groups at a minimum follow-up of 2 years PO. Increased levels of inflammatory cytokines have been found in stiff shoulders after RCR. There is evidence that ttt with PEMFs consistently reduces these levels.

Neuromuscular Electrical Stimulation

Reinold et al (39) evaluated the effect of NMES of the IS on shoulder ER force production after RCR surgery compared the muscle force of the ER using two groups, one with NMES and one without NMES. applied one session of NMES with maximal intensity within the participant's comfort level, at a frequency of 50 pulses per second, using a symmetrical waveform, and a one-second ramp time, they found significant increase of volitional muscle force production during ER (peak shoulder ER force increased by 22%) regardless of the age of the patient, gender, size of tear, number of days PO and level of NMES intensity.

NMES application is safe and effective at a mean of 10.5 days PO and may be applied concomitantly to maximize force production during standard rehabilitation exercises, such as isometric, isotonic tubing, and dumbbell exercises, as well as during manual resistance and stabilization techniques. The patient may be able to achieve improved active elevation by enhancing the force couple balance of the ER/IR of the RC. This force couple functions synchronously to center the humeral head during active arm elevation without superior humeral head migration and a subsequent shoulder "shrug" sign. This may ultimately lead to improved functional gains and PO outcomes in the RCR patient (39).

NMES has been recommended as an adjunct treatment for neuromuscular reeducation and strengthening due to the muscle inhibition resulting from PO pain and joint effusion (60).

NMES enhances force (torque) production, muscle recruitment, and ultimately results in improved gait and a quicker recovery of function (61). Although NMES may be more effective in increasing isometric strength of the muscle, a carryover effect may enhance the other types of muscle contractions (concentric, eccentric), which may lead to improved functional gains for the patient (62).

Cryotherapy

Cryotherapy (ice 15-20 minutes every hour) used to decrease pain and inflammation (1). Van der meijden et al (2) recommended the use of a home cryotherapy device for 10–14 days PO. Cryotherapy is used PO to decrease pain, swelling, muscle spasm, and minimize the inflammatory response (2).

Singh et al (63) in their prospective, randomized investigation evaluated the efficacy of cryotherapy on subjective responses after both open and arthroscopic procedures on the shoulder.70 patients were randomly assigned to one of two study groups: 1- continuous cryotherapy group and 2- age-matched control group. VAS were used to assess subjective responses on PO days 1, 7, 14, and 21. On day 1, patients receiving cryotherapy reported significantly less pain during sleep and significantly more comfort in bed and rated their sleep as more restful than the control subjects. During days 7 through 21, cryotherapy subjects reported a significant reduction in frequency and intensity of pain, as well as less pain during shoulder rehabilitation, than the control subjects. These results indicate that cryotherapy is an effective method for PO pain control because it decreases the severity and frequency of pain and allows a return to normal sleep patterns while increasing overall PO comfort and satisfaction.

Osbahr et al (64) in their prospective ,randomized and controlled clinical trial reported that cryotherapy causes significant reduction of both GHJ and SA space temperatures during the first 23 PO hours. This decrease in temperature may decrease proteolytic enzyme activity that can be detrimental to articular cartilage. It also shows that cryotherapy is an effective nonpharmacological method of pain control.

On the other hand, Levy et al (65) on penetration of cryotherapy in ttt after shoulder arthroplasty found that cryotherapy does not reduced SA and GHJ temperature in their 10 patient randomized control study.

Speer et al. (66) in a prospective study comparing PO patients fitted with cryotherapy to those that did not found cryotherapy resulted in less PO pain and perceived need for narcotics. Patients also had less swelling and pain during rehabilitation, resulting in improved rehabilitation effort (66).

Aquatherapy

Physical properties of the water are the basis for its creative uses in rehabilitation; they include 1- buoyancy which allows initiation of resistive exercise at a low and protective level that can be graduated up depending on the direction of movement (1), buoyancy-assisted exercise occurs when movements are toward the surface of the water, buoyancy-supported exercises are parallel to the bottom of the pool and buoyancy resisted exercises are performed toward the bottom of the pool (1,67). 2- hydrostatic pressure which decreases or prevents increasing the effusion during the exercise and dampens sympathetic nervous system activity (68) thus decreasing the pain (5,67) and 3- viscosity which provides the most common form of resistance training (67).

Aquatherapy can be started during week 2-6 . Once the surgical incisions have healed, Gentle stretching and passive motion can be performed in a pool, 2 to 3 days per week, for 15 to 20 minutes per session. Aquatherapy with neck deep water at 6 to 8 weeks ,advanced with the addition of active motion, at 10 to 12 weeks the patient can do underwater resistance exercises. Aquatherapy decreased muscle activation allow for earlier active motion improving the GH motion without compromising the integrity of the repair (1,2,67). The warmth and buoyancy of water may block nociception by acting on thermal receptors and mechanoreceptors, thus influencing spinal segmental mechanisms (69,70) and enhance stretching (2). In addition, the warmth may enhance blood flow, which is thought to help in dissipating algogenic chemicals, facilitate muscle relaxation (71), increases soft tissue extensibility and has profound effect on the properties of collagen (67).

Water makes certain movements easier to perform and optimal positions easier to maintain so, the pool is an ideal place to improve shoulder mobility (1,67).

Exercises performed against the water's resistance almost always elicit concentric muscle contractions. Eccentric muscle contractions are most easily elicited using large, buoyant objects. Additionally, rapid, alternating movements can generate eccentric contractions as the muscle attempts to slow the limb for the change in direction (67).

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The resistance to an exercise can be increased using viscosity in 2 ways. First, increasing the surface area by use of gloves, paddles, or others. Second, increasing the speed of exercise (67).

Physiologic responses of water immersion both at rest and during exercise include SV and cardiac output (CO) increase, while heart rate (HR) decreases or remains unchanged depending on the water's depth, position of the athlete in the water, and exercise efficiency. Additionally, the hydrostatic pressure on the chest challenges chest expansion and may be problematic for individuals with reduced lung capacity, breathing difficulties, or general fear of the water. Warm water can also place an additional burden on the cardiovascular (CV) system as it attempts to prevent overheating. Intense training of athletes should take place in water between 27°C and 28°C to prevent any heat-related complications. However, for simple rehabilitation exercises that are not CV demanding, athletes can safely exercise at 33°C to 34°C (67).

The benefit of water-based, open-chain, UE exercise is the trunk muscle cocontraction. Arm movement through the water tends to promote balance and stability. Thus, simple, open-chain arm exercises such as bilateral shoulder flexion and extension or bilateral PNF diagonals also serve simultaneously as trunk-stabilization exercises. Resistive boards can be held underwater in front of the athlete to perform a push-pull motion for scapular protraction and retraction to strengthen the rhomboids, trapezius, and serratus anterior (67).

Athletes who perform sports requiring closed kinetic chain (CKC) movements and those who need enhanced proprioception and stability can benefit from CKC exercises as dips at the side of the pool and overhead push-pulls in the supine or prone position. Floating in a prone position, the athlete can press flotation equipment toward the bottom with 1 or both hands. This exercise will challenge balance and proprioception as well. An excellent but often overlooked UE training technique is swimming. Not only does it train the UE, but it also provides CV benefits, neuromuscular coordination, and stretching and elongation through the legs, trunk, and UEs (67).

Many of the shoulder- and core-stabilization exercises constitute exceptional proprioceptive exercises if the visual cues are removed. The athlete is asked to perform these exercises with the eyes closed and in a variety of postures and positions (67).

Kamioka et al (71) in their systematic review of nonrandomized controlled trials on the curative effects of aquatic exercises found that the warmth may enhance blood flow, which is thought to help in dissipating algogenic chemicals, and it may facilitate muscle relaxation. They cannot suggest that aquatic exercise is more effective than land exercise for pain relief in locomotorium diseases. They were unable to offer any conclusions about the effects of this intervention due to insufficient evidence.

Several studies (72-74) evaluated the effect of aquatic exercises as compared to land-based exercises. During the 3rd and 6th follow-up weeks, two studies (72,73) found small to moderate improvements in ROM and pain, favoring aquatic exercises. Brady et al (72) in an RCT (feasibility study) found that at 6 weeks PO,
the final outcome in motion was a mean forward flexion PROM increase of 46° with aquatic compared to land-based exercises. However, the authors found no significant difference in ER ROM or function score. thus aquatic exercises can be utilized to complement land based AAROM in restoring GH ROM (72) as well as allowing graduated resistant activities in a more protective and conductive environment during the early phases of the shoulder rehabilitation (2) . Dainty (73), with a randomized controlled trial, found no statistically significant difference between aquatic and land-based groups in function or pain.Delbrouck et al (74) compared inpatient aquatic therapy with outpatient aquatic therapy and found no significant difference in ROM between the groups. However, they found reduced pain on the PO 15th day for the inpatient aquatic therapy group.

Fujisawa et al (75) found that exercises performed at 90° of abduction in the water were associated with significantly less electromyographic activity than land-based exercise.

Joint mobilization

Joint mobilization techniques can be used to address joint stiffness and PROM deficits. Muraki et al demonstrated that GH
distraction as well as anterior and posterior translational glides do not significantly alter stress on repaired SS tendons with the arm in resting position (30^{O} abduction in the scapular plane) (76). In particular, posterior translational glides
have shown to significantly increase ER ROM in patients with stiff shoulders. These mobilizations are performed after positioning the extremity in the maximum available abduction and ER (77). The glides can be included in the early stages of rehabilitation at lower grades to assist in decreasing pain and guarding. Once the patient has progressed to 4–6 weeks PO, the mobilizations can be progressed to higher grades with the extremity positioned into maximum available abduction and ER.

The Maitland approach for mobilizations allows for both pain reduction and joint capsule stretching (46) without the patient providing any exertion (38). This approach uses the patient's verbal treatment responses to guide each subsequent treatment (78) .The larger-amplitude mobilizations are preferred when there is tissue resistance through a larger ROM, and the smaller-amplitude movement is preferred when the tissue resistance is concentrated in a smaller area (79). The mobilization adjusted at each PT session according to the patient's pain responses to the mobilization (79). Mobilizations were performed with the patient in supine and prone positions and with varying positions of the UE as needed to stretch the capsule. As the

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ROM increases, the resistance is felt later in the joint's ROM (79).

Carlson and Hadlock in their case report of a 48-year-old woman with post-polio syndrome had RCR followed by PT intervention in form of Maitland mobilization and mild functional exercises showed return to independent status with excellent retention (40).

Manual vs. Mechanical CPM

The benefits of continuous passive motion (CPM) appear to be more significant when it is used in conjunction with PT. CPM does have short term benefit in the improvement of ROM when it is prescribed with PT, but it lacks clear long term benefits and incurs higher overall cost (1). Most of studies evaluated the effect of CPM found small to moderate improvements in pain, ROM, and muscle strength, favoring CPM. These findings were noted during short-term follow-up: at PO 1st week, 3rd week, and 6th month (37).

Dockery et al (80) found no difference in activity of RC muscles between mechanical CPM and manually-assisted CPM in an electromyographic study. Higher muscle activity was noted during patient self-assisted ROM exercises as compared to mechanical CPM.

El-Zahaar et al (81) found that 92% of the participants experienced PO pain reduction, and 70% had improved shoulder function when CPM was used during rehabilitation. Lastayo et al (82) compared CPM with manual PROM. They found significantly less pain with CPM, during the PO first week, compared to
manual PROM. The authors also found a marginal increase in shoulder elevator strength with CPM, at sixth months follow-up. However, ER and forward flexion ROM demonstrated no significant between-group differences at one month, one year, or two years follow-up. Raab et al (83) compared CPM with manual PROM. They found improvement in the ROM and in pain scores with CPM as compared to manual PROM. Statistically, significant differences in outcomes occurred only at the 3 week PO time point. Although these studies (82-84) found a short-term improvement, they did not find any long-term effects of CPM.

Li et al (84) suggested that CPM in rabbits promoted basic fibroblast growth factor expression, leading to enhanced type III collagen synthesis at the tendon-bone interface in the early stages of tendon-bone repair after acute rupture of the SS tendon, thereby contributing to tendon bone recovery after RC injury.

Garofalo et al (85) in their prospective randomized study of effects of one-month CPM after ARCR, 100 patients allocated to one of two different PO PT regimens: passive self-assisted ROM versus passive self-assisted ROM exercise associated with use of CPM for a total of 2h per day, for 4 weeks. After this time, all the patients of both groups underwent the same PT protocol; they found that passive self-assisted ROM associated with CPM provides a significant advantage in terms of ROM improvement and pain relief when compared to passive self-assisted exercise alone, at the short-term follow-up. No significant differences between the two groups were observed at 1 year PO.

Introduction of repetitive tensile stress during the maturation process may be beneficial in helping the orientation of biomechanically more robust type I collagen fibers. PROM should be performed gently and in a controlled manner within a safe range. Certainly end of range pressure (stretching) should be avoided (1).

One of the primary concerns following RCR is shoulder stiffness. However, the rehabilitation specialist should not be overly aggressive in obtaining ROM, which could compromise the repair. There needs to be a balance between applied force and tissue-healing constraints. The best approach for performing PROM while minimizing muscular activity was to have the PT perform the exercises with the patient in supine or when using CPM device. Conversely, the surrounding musculature was most active when doing the rope and- pulley ROM exercise (9).

Ghodarda et al (9) preferred PROM exercise initially, then to progress to AAROM exercise once adequate tissue healing occurs and restrict passive shoulder ER to 45° with the arm at 30° to 45° of abduction in the scapular plane, and forward elevation to 120° to avoid excessive tension on the repair.

The use of pulleys is controversial as EMG studies have shown muscle activation and that the RC is not "quiet" with these activities, so true passive ROM is not achieved (42).

Strength training

GH and ST kinematics, as well as soft-tissue compliance, should be optimized so that a strengthening program can be safely initiated without pain and in proper form. Attempts to strengthen a stiff shoulder can cause pain, SA impingement, and excessive stress on the repair (1,2), Advanced RC strengthening started at 16-22 weeks PO, especially of the posterior cuff, To isolate IS and TM, perform ER exercises of the shoulder at 45^{O} of abduction utilizing elastic resistance while in a standing position. Then, to activate SS muscle activity, perform ER exercises at 90^{O} of abduction. To strengthen the serratus anterior, pushup with a plus exercise progression from a wall, to a chair, then finally to the floor.

Heiderscheit et al (86) evaluated the effects of an 8-week isokinetic training and 8-week plyometric training program on softball throwing distance and power. Although those who trained isokinetically significantly improved their scores on the isokinetic device, neither training group had an improved softball throwing distance.

Manual resistance for the scapular motions from sitting started early PO (1,35). The scapular stabilizers play a vital role in the rehabilitation of RC (3). Strengthening exercises should be approached with caution to prevent stress applied to the healing tissues (9). Stress applied too early or too aggressively could lead to gap formation, pain, re-tearing of the repair, and poor outcomes. When appropriate, we believe isometric exercises should be performed to prevent muscular atrophy and to minimize RC inhibition . Rhythmic stabilization exercises in supine and within the balanced position (100° of elevation and slight horizontal abduction). In this position, the PT provides resistance in an alternating manner to require an isometric contraction of the shoulder muscles. This exercise is completely safe for patients who have undergone a RCR restoring dynamic stabilization of the GHJ (9,35).

An adequate dose of mechanical load could improve the repairing, but an insufficient of inadequate stimulation could inhibit or prevent it. Eccentric training (The contraction of a muscle for decelerating a load while the muscle and the tendon are stretching or remain stretched) should be used aiming improvement of the tendon degeneration and decreasing pathological increased capillary tendon flow without deterioration of local tendon microcirculation. The mechanical loading should be started as soon as the pain allows (87).

To strengthen the trapezius and rhomboid musculature, the standing sport cord row exercise is used. To strengthen the biceps and triceps brachii muscles, conventional biceps curl and triceps extension exercises are used with either isotonic free weight resistance or elastic tubing (2). Standing position while performing external rotation of the shoulder at 45^{O} of abduction utilizing elastic resistance. This ensures high levels of IS and TM activation (1,2).

Plyometrics for the UE train the shoulder and UE musculature to dissipate forces.Typically the patient will start by performing bilateral throws and progress to unilateral throws against a wall, rebounder, or by involving a partner using progressively heavier weighted balls. These exercises should start at positions at or near shoulder height progressing to the overhead position (2).

Return to Sports

RTSs (such as golf, tennis and swimming) or strenuous work depends on the patient's surgical variables (size of tear, tissue quality, concomitant procedures) and the rehabilitation recovery process not before 6months. Often patients are placed on an interval sports program to gradually increase the functional activities (9).

Prior to RTS, patients must progress through and complete interval sport programs. These are essentially rehabilitation guidelines that simulate sports and recreational activities. They are intended to safely return an athlete to competition as soon as possible while progressively applying appropriate forces to healing structures. Patients who are not athletes still benefit from a functional progression that simulates ADLs and work-specific activity. It is recommended that these intensive sports programs should only start after an athlete has completed an adequate CV warm up. The program should be performed three times per week with at least one rest day in-between sessions ,To progress to the next level the patient must be able to demonstrate the prior level without pain or limitations. A maintenance exercise program focusing on CV endurance and flexibility along with ST, RC, LE and core strength should be performed on alternate days (2).

Depending on the type of work , the patient should return when comfortable, pain free, and is able to perform the duties without detriment to the rehabilitation protocol. Manual laborers should only return to work when they have completed the rehabilitation and have acquired ROM and strength as the normal side (1).

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