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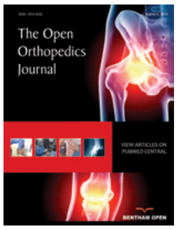

REVIEW ARTICLE

Prognosis Driven Rehabilitation After Rotator Cuff Repair Surgery

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Abstract:

Background:

Rehabilitation after rotator cuff repair surgery has been the focus of several clinical trials in the past decade. Many illuminate new evidence with regard to the prognosis of structural and functional success after surgery.

Methods:

A selective literature search was performed and personal physiotherapeutic and surgical experiences are reported.

Results:

Post-operative rehabilitation parameters, namely the decision to delay or allow early range of motion after surgery, play a large role in the overall success after surgery. Using a prognosis driven rehabilitation program offers clinicians a means of prescribing optimal rehabilitation parameters while ensuring structural and functional success. This commentary aims to synthesize the evidence in a spectrum of prognostic factors to guide post-operative rehabilitation.

Conclusion:

The optimal rehabilitation program after rotator cuff repair surgery is debatable; therefore, we suggest using a spectrum of prognostic factors to determine a rehabilitation program suited to ensure structural and functional success, quickly and safely.

Keywords: Physical therapy, Protocol, Rehabilitation, Rotator cuff repair, Shoulder.

INTRODUCTION

A brief analysis of the US National Library of Medicine (Pubmed) citations specific to 'rotator cuff repair' showed a 380% increase in citations from 2005-2015 compared to 1995-2005. This surge in attention to rotator cuff repair (RCR) surgery includes a significant number of papers focusing on rehabilitation and prognosis. The goal of RCR surgery is to restore the normal anatomy of the rotator cuff in order to reduce pain and restore function. Subsequently, the objective of the post-operative rehabilitation is to ensure the structural and functional success of surgery. Success, however, is based on numerous factors, including the symptom severity, tear size and retraction, fatty infiltration and muscle atrophy, failure of previous treatments, health status, and factors that affect outcome and healing. These factors constitute 432 possible combinations of factors, which the American Academy of Orthopedic Surgeons established in the appropriate use criteria for optimizing the management of full-thickness rotator cuff tears [1]. While the intent of research regarding the treatment of rotator cuff tears is to critically evaluate the efficacy of possible treatment options,

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the exponential growth of emerging evidence can be daunting for a clinician to synthesize and interpret. Therefore, we aim to provide a synthesis of evidence regarding the prognostic factors leading to the structural and functional success of RCR surgery in this commentary. Secondarily, we aim to offer rehabilitation suggestions based on these prognostic factors.

Structural Versus Functional Success

Success after RCR surgery can be defined in two ways: functional and structural. Functional success refers to elements of patient satisfaction and quality of life. These factors are typically measured by outcome scores, namely the American Shoulder and Elbow Surgeons (ASES) score, the short or long form of the Disability of the Arm, Shoulder and Hand (DASH) score, the Western Ontario Rotator Cuff Index (WORC), the Constant-Murley score, the Single Assessment Numeric Evaluation (SANE), and the short forms 12 (SF-12) and 36 (SF-36). In general, these measures mesh constructs of pain, disability, and function as they relate upper extremity impairments and demands.

Structural success refers to the success of the surgical procedure in restoring rotator cuff anatomy, or, in simple terms, when the repair remains intact. Structural success is typically assessed using diagnostic ultrasound (US) and/or magnetic resonance imaging (MRI) and/or computed tomography arthrography (CTA) [2]. It would seem logical to infer that structural success will reduce impairments (*i.e*. ROM and strength), leading to functional success; however, functional success is often observed in patients with failed structural healing [3, 4].

In fact, the relationship between clinical outcomes and structural healing was the topic of a systematic review that concluded structural healing could not definitively predict better clinical outcomes [5]. This finding was the impetus to a prospective, multi-center clinical trial in which physical therapy was used as the initial treatment for patients with atraumatic rotator cuff tears [6]. Interestingly, a standard physical therapy program yielded 75% success with failure defined as the patient opting to undergo RCR surgery. Moreover, patients who elected to have surgery typically did so within the first 3 months of conservative management. These results indicate the importance of physical therapy at restoring function in the upper extremity in the presence of rotator cuff insufficiency. Physical therapy is especially important since regaining strength after certain RCRs is questionable, particularly larger tears with increased fatty infiltration [7, 8]. Therefore, physical therapists who treat patients who undergo RCR surgery should utilize a comprehensive strategy with structural and functional success in mind.

Structural Success, Tissue Healing and Early Motion

Normal soft tissue healing after tendon repair follows a three-stage process - initial inflammation, fibroblastic (proliferative) activity, and remodeling [9, 10]. During the first stage of inflammation, vascular permeability increases and inflammatory cells carrying cytokines and growth factors infiltrate the area [9]. This stimulates fibroblastic cellular proliferation, yielding haphazard type I and III collagen formation at the tendon-bone junction. With time and appropriate loading, more type I collagen is expressed and the fiber orientation transitions to a more parallel orientated, stronger layout [5, 11 - 13]. Small, full-thickness tears in the rotator cuff tend to follow a normal healing process, whereas larger tears exhibit fewer fibroblasts and limited cell proliferation, thus reducing the potential for physiologic healing [14].

Large tear repairs tend to re-tear between 3-26 weeks after surgery [13]. This broad time frame coincides with the variable healing time of the proliferative and remodeling phases, both of which are negatively affected by local and systemic confounding factors [9, 10, 15]. Conversely, Boileau *et al*. [16] concluded that isolated supraspinatus tears led to superior healing at 29 months follow-up. They also found that average shoulder forward elevation strength was higher in patients with confirmed tendon healing *versus* those with a persistent defect. This discrepancy in structural healing left researchers to question the timing of range of motion after surgery is performed.

Several animal model studies in the past decade have focused on comparing early to delayed motion after RCR surgery in the initial phase of rehabilitation [17 - 19]. The primary outcome of these studies is structural success. One such study compared two weeks of absolute immobilization (continuous immobilization) to relative immobilization (immobilization with PROM) in rodents with acute supraspinatus repairs [17]. The rodents were then “remobilized” using a gradual progression of cage activity to treadmill running. At the 6^{th} post-operative week, mechanical and histologic testing measures were not statistically different among the groups. Although ROM improvements favored the immobilization group, the authors concluded that “detrimental” effects occur with early range of motion after RCR surgery. A similar study compared cage activity to a treadmill running protocol after 2 weeks of immobilization [18]. At the 12^{th} post-operative week, rodents in the exercise group demonstrated decreased ROM and inferior mechanical and histological tendon quality. These results are not surprising because they exhibit a scenario of tissue overloading. When a rehabilitation program more analogous to a human RCR protocol was studied, Zhang *et al*. [19] found no differences in biomechanical, structural or MRI signaling in RCR surgeries performed on rabbits when relative immobilization was compared to absolute immobilization for 6 weeks. In comparison, rodents were exposed to early closed kinetic chain activity. Closed kinetic chain activity is considered a high-level strengthening activity in published rehabilitation protocols [20 - 22] and typically reserved for later phases of rehabilitation.

The results of the aforementioned animal studies prompted several researchers to investigate early *versus* delayed rehabilitation programs in human subjects. Researchers sought to answer the following clinical questions: does early range of motion in RCRs lead to structural failure? Are functional outcomes better with earlier or delayed motion programs? And, does delayed motion lead to shoulder stiffness? The deluge of clinical studies influenced recent systematic reviews, some with meta-analyses [23 - 26]. Briefly, Chang *et al*. [23] proposed an algorithm suggesting that patients presenting with risk factors predictive of structural failure should undergo a delayed motion program, and patients with risk factors suggestive of stiffness but not structural failure may be better suited for an early ROM program. Lastly, the authors proposed that patients without healing risk factors follow a delayed program due to cost-savings; these findings should be interpreted with caution because a cost-analysis comparing the impact of early *versus* delayed motion does not exist in the literature.

Kluczynski *et al.* [24] recently performed two systematic reviews with meta-analyses of Level 1 and Level 1-4 studies. The pooled data favored early PROM (initiated within 1 week of surgery) for >1cm tears and delayed motion (defined as beginning 3-6 weeks after surgery) for >5cm tears. No significant differences in re-tears were found in tears > 3cm, 3-5cm, and >3cm, regardless of repair type, leaving the decision to allow early motion to clinical reasoning and prognostic factors. Tears >5cm demonstrated greater risk of tearing (RR: 2.82). Using similar methodology, the same group compared early *versus* delayed *active* ROM and found no difference in re-tear rates in tears >3cm with double-row suture anchor techniques; however transosseous and single-row anchor techniques had significantly higher re-tear rates [25]. Tears exceeding 3cm had higher rates of re-tears leaving the authors to conclude that active ROM should be delayed until 6 weeks after surgery.

Prognostic Factors of Functional and Structural Success

Prognosis is a means of predicting the course of a disease and prognostic factors are characteristics associated with the outcome of a disease [27]. In terms of RCR surgery, prognostic factors are a means of determining the structural and functional success of surgery. The type of surgical procedure and therapy are two factors among a long list of factors that affect one another in the overall success of surgery. An evaluation-based approach to rehabilitation has been recommended as a means of ensuring success [21]. Part of this approach is based on using prognostic factors. We recommend using these factors in a prognostic spectrum to guide the post-operative management of patients who undergo RCR surgery. Table **1** outlines several prognostic factors previously defined by evidence that drive the functional and structural success of RCR surgery. Patients with specific risk factors negatively affecting the overall surgical success should be directed to a conservative rehabilitation program; whereas those patients with factors associated with better healing potential and functional success may undergo a more rapid progression of postoperative rehabilitation. Table **2** outlines our recommended rehabilitation parameters, which have been outlined in more detail in a previous publication [22].

Age is a primary factor affecting structural success of RCR surgery. Several studies show that patients younger than approximately 50 years of age demonstrate better tendon healing than those above the age of 60-65 years of age [28 - 32]. Increasing age is also associated with poorer functional outcomes [32, 33] and longer recovery times [32]. As age increases, typically so does tear size. Larger tears are associated with higher failure rates [29 - 31], recovery greater than six months [13, 32], and greater tendon retraction [34]. Larger, atraumatic tears tend to exhibit greater fatty infiltration (FI) and muscle atrophy (MA) [35 - 37]. Various methods are used to determine the degree of FI and MA [35 - 39], however the most commonly utilized method is the Goutallier scale, which classifies minimal FI and MA as stage zero and severe as stage four [35]. Repair failure reaches 100% in tears associated with greater than stage 2 FI and MA, whereas tears with less than stage 1 FI and MA achieve greater than 92% healing [28]. Finally, larger tears appear to have poorer histological quality with decreased propensity for healing [14].

Factors extrinsic to the rotator cuff, yet affect healing and functional success include bone mineral density (BMD), smoking, diabetes mellitus (DM), and obesity. Osteopenia (BMD: -1 – -2.5) and osteoporosis (BMD > -2.5) have an increased risk of structural failure, which is likely due to decreased pull-out strength of anchor fixations [4]. Nicotine propogates vasoconstriction to rotator cuff tendons further reducing blood flow to an already hypovascular region [40]. This leads to delayed healing potential, which has been observed in controlled rodent experiments [41]. Furthermore, tear size and severity is associated with the number of cigarettes smoked in a lifetime [40], small improvements in functional outcomes and increased post-operative pain [42]. Although DM does not directly affect the quality of healing [30], the presence of DM increases the risk of post-operative stiffness [43] and leads to poorer functional outcomes [33]. Therefore, an early ROM may be more appropriate for patients with DM. Patients with a body mass index of >30 are considered obese. These patients are prone to longer hospital stays after RCR surgery, higher failure rates, poorer outcome scores and limited ROM [44].

Table 1. Prognostic Spectrum. Shoulder prognostic spectrum to recommend the type of post-operative rehabilitation program after RCR surgery.

	Moderate	Intermediate	Conservative
Age	< 50	50-60	>60
BMD	> -1	-2.4 to -1 (penia)	< -2.5 (porosis)
FI + atrophy	stage 0	stage 0-1	stage 1-2
DM	+	+	-
BMI	<25	25-30	>30
Smoker	-	-	+
Tear size	partial -small (1 tendon)	Small-medium (1-2 tendon)	Large-Massive (2+ tendons)
Retraction	none	in-between	>Glenoid
Tissue Quality	Good	Fair	Poor
Pre-op Strength	Good	Fair	Poor

(BMD: Bone Mineral Density, FI: Fatty Infiltration, DM: Diabetes Mellitis, BMI: Body Mass Index).

Table 2. Prognosis-based Rehabilitation. Rehabilitation parameters for each post-operative rehabilitation protocol.

	Moderate	Intermediate	Conservative
Sling	comfort-2 weeks	4-6 weeks	6+ weeks
PROM	begin: Immediate FPROM	begin: 0-4 week 30 ER, 90 ABD, 120 FE FPROM: 4-6 weeks	begin: 4-6 weeks 30 ER, 90 ABD, 120 FE FPROM: 6-8 weeks
AROM	0-2 weeks	4-6 weeks	6-8 weeks
Strength	4-6 weeks	8-10 weeks	10-12 weeks

(PROM: passive range of motion, AROM: Active Range of Motion, FPROM: full passive range of motion, ER: external rotation, ABD: abduction, FE: forward elevation).

There are also pre-operative factors that affect functional success after RCR surgery. These are factors that can be influenced pre-operatively with a rehabilitation program [11]. Lapner *et al*. [45] determined that pre-operative strength was the best predictor of post-operative strength at the 12th post-operative month in a prognostic study. Pre-operative stiffness is suggested as a negative predictor of functional outcomes at 6 months after surgery, even when a concomitant capsular release was performed [32]. This may explain why post-operative patients who participate in higher levels of sporting activities score higher on physical quality of life components of the SF-36 [33]. Given that a rehabilitation program is successful at improving functional outcomes in the presence of rotator cuff insufficiency [6], these factors warrant pre-operative physical therapy when ROM and strength impairments are identified. Pre-operative treatment of patients with low BMD and BMI should be considered to improve the probability of functional and structural success.

Initial Phase of Rehabilitation: Shoulder Mobility and Graded Manual Therapy

Restoration of shoulder complex mobility after any type of RCR is the initial goal in the initial phase of rehabilitation [20 - 22], but determining the right timing and progression of therapy can be a challenge. The degree of post-operative pain, muscle guarding, swelling and scar tissue formation vary after RCR surgery, suggesting treatments should be case-specific. It is also critical to continuously monitor a patient's tolerance to ROM components, as shoulder pain during or after treatment can help guide therapy. Kelly, McClure and Leggin [43] proposed an irritability classification for treatment of adhesive capsulitis, which we recommend as a guide to dose RCR rehabilitation (see Table **3**). The authors identified three levels of irritability - high, moderate, and low. The degree of irritability should match the load, duration and frequency of interventions applied to the patient's shoulder. For instance, patients with high irritability should be prescribed interventions that do not increase the level of irritability. This includes low grade mobilizations and ROM exercises within pain tolerance. Patients with low irritability may be prescribed mobilizations and ROM exercises to end-range. Load, frequency and duration.

Table 3. Adapted from: Kelley MJ, McClure PW, Leggin BG. Frozen Shoulder: Evidence and a Proposed Model Guiding Rehabilitation. J Orthop Sports Phys Ther. 2009; 39(2):135-148.

Low	Moderate	High
Low Pain	Moderate Pain	High Pain
No resting or night pain	Intermittent night or rest pain	Consistent night or rest pain
Low disability on DASH or ASES	Moderate disability on DASH or ASES	High Disability on DASH or ASES
Minimal pain at end ROM with overpressure	Pain at end ROM	Pain prior to end ROM
AROM same as PROM	AROM similar to PROM	AROM less than PROM secondary to pain

Glenohumeral Arthrokinematics

Glenohumeral joint (GHJ) capsule and ligamentous mobility play an important role in the static and dynamic positioning of the humeral head in the glenoid concavity. Restoration of arthrokinematic mobility should occur to set the stage for non-compensatory, pain-free osteokinematic ROM. Deficits with inferior capsular mobility is associated with pain and increased superior humeral head migration [46], rotator cuff weakness [47], and subacromial impingement [47 - 49]. Evidence also suggests that superior humeral head migration has been associated with attritional damage of the primary stabilizers of the glenohumeral joint, and can contribute to chondral degeneration [50].

Manual therapy techniques are used to restore joint arthrokinematics. The irritability classification can further be applied to dosing of manual therapy techniques previously discussed. Muraki *et al*. [51] found that there was gap formation within a repaired supraspinatus with grades II and III inferior gliding with the arm at 0 degrees. Their study indicated that translatory glides can be safely performed with the arm positioned at 30 degrees of abduction if the repair was performed at 0 degrees abduction [51]. With time, and as pain decreases and disability scores improve, graded mobilizations can increase in intensity and duration, and progress by mobilizing the glenohumeral joint in the hypomobile, closed-packed position (abduction and external rotation). Johnson *et al*. [52] found that limitations with external rotation can be effectively addressed with posteriorly directed glides at end-range abduction and external rotation [52]. Inferior capsular mobilizations can be implemented to normalize the inferior head gliding, which occurs during shoulder elevation - abduction and flexion.

Scapular Kinesis

Altered scapular positioning and kinematics have been associated with shoulder impingement, pain, stiffness, rotator cuff tendonopathy, rotator cuff tears, glenohumeral instability, and adhesive capsulits [46, 53, 54]. Scapular mobility should be assessed, both statically and dynamically, at the scapulothoracic (ST), acromiocalvicular (AC), and sternoclavicular (SC) joints. Hypomobililty or hypermobility at just one aspect of the shoulder coupling can affect the quantity and quality of shoulder movement, specifically with elevation [46, 53, 54] Restoration of normal scapular upward rotation mobility, and stability with concurrent humeral elevation, is an important step towards normalizing the synchronous relationship of GH and ST ROM. Decreased upward rotation of the scapula has been identified with individuals who have shoulder pain *versus* those who do not [47, 53].

Lawrence *et al*. [53] found that symptomatic shoulder pain was associated with reduced SC posterior rotation and elevation during both humeral abduction and scapular plane elevation. Because there is no muscle directly acting on this joint, SC motion occurrs as a result of scapular upward rotation and subsequent tension through the AC joint and coracoclavicular ligaments [51, 53]. This research supports the necessity of increased focus on SC and AC joint mobilization to restore the quantity and efficiency of the scapular coupling, but one must also incorporate dynamic strengthening of the muscles that act on the scapular force couple - upper/middle/lower trapezius, rhomboid major/minor, levator scapula, and serratus anterior. If ST kinematics are not normalized, shoulder impingement syndrome may occur or re-occur, and there can be an increase in the relative risk or cuff re-tearing [47, 54, 55].

Promoting proper scapular kinesis can be trained very early in rehab. Isometric scapular retraction can begin in standing or sitting, and can be progressed to the prone position. Scapular elevation compensation with overhead ROM can be secondary to GH or ST joint hypomobility, cuff weakness, pain, and/or a neuromuscular deficit. A therapist's use of tactile cuing at the interscapular muscles can be useful to maximize muscle activation and cue for specific scapular motion, such as recruitment of the lower trapezius when upper trapezius activity is dominant. Early exercises include manually resisted scapular isometrics and active movements that avoid glenohumeral and cuff activity. These may be progressed to exercises against gravity in the active phase, where synchronous and rhythmic motion between the ST and GH joint should be the focus.

Early Strength Phase: Muscle Physiology of the Rotator Cuff

The rotator cuff is comprised of four muscle tendon units - the supraspinatus, infraspinatus, teres minor, and subscapularis. At the insertions, the tendons of these muscles fuse together to form a continuous structure [9]. The cuff is then defined by two surfaces - the bursal and articular surfaces, with the bursal surface being reinforced by the coracohumeral ligament anterosuperiorly, and the articular side covered by the synovialized joint capsule lining. The construct of the GH joint is designed to be a highly mobile segment. With that, the cuff muscles are positioned on the scapular platform to provide dynamic support through short lever arms. Together, the axial force couple of the subscapularis and infraspinatus/teres minor when contracted creates a compression force that centers the humeral head in the glenoid concavity. In a healthy shoulder, the cuff muscles dynamically maintain the humeral head compressed and centered during elevation, as the humeral head glides inferiorly and rolls posteriorly or anteriorly. Restoring the dynamic balance of the rotator cuff strength is imperative to reduce the risk of pathological GH mechanics and subsequent subacromial impingement or cuff tearing.

Initiation of the strength training is a component of the second phase of RCR, and the timing remains variable based on prognostic driven factors [22]. Criteria for progression into this phase is adequate PROM and non-compensated GH and ST AROM [21]. Surrounding, non-repaired rotator cuff muscles should also be taken into consideration when initiating strength training; subscapularis, infraspinatus and teres minor muscle support affects the static and dynamic humeral head position within the glenoid [9, 47.] Increasing the support from the surrounding cuff musculature should decrease the direct stress/strain on a repaired supraspinatus, which may increase the short- and long-term survivorship of the soft tissue.

Strength training should focus on endurance, using high repetition, low resistance parameters. Rhythmic stabilization, a form of open chain isometric training, can also be performed with gradually increasing pressure and duration of multidirectional holds to stimulate co-contractions at the pectoral girdle [21, 22]. Internal and external rotation strengthening can be performed using resistance bands in standing, or in side lying with hand weights. Supraspinatus muscle activation is safely targeted with a full-can motion [47]. After good muscle activation and endurance is established, strength and power oriented training through higher resistance can be initiated using a periodization format to load the healing tendon-bone interface and stimulate healthy remodeling [9, 10, 56].

Handheld dynamometry is a helpful tool to determine a limb symmetry index (LSI), which can then be helpful when establishing a strength goal. When evaluating patient's readiness to return to sport, having a 90% strength index or greater is a good baseline goal, but a further evaluation of functional movement patterns and dynamic endurance should be performed on both sides to ensure that even the uninvolved side is "healthy" and free from dysfunctional movement patterns and muscle imbalances. The sport of interest should also be scrutinized. Overhead throwing sports will require more shoulder rotation mobility, strength and eccentric control, depending on the extremity dominance. For example, golf will require specific mobility and stability requirements at the shoulder girdle, otherwise compensation at other segments may occur [57]. Whatever the sport may be, an integrated approach must be taken to address core strength and functional shoulder mobility and strength capacity. Regardless, patients should use a slow re-introduction back into a sport using irritability as a guide his or her progression.

CONCLUSION

Predicting surgical outcomes using pre-, intra- and post-operative prognostic factors has been a topic of interest in the literature. Functional shoulder recovery after RCR surgery is the terminal goal, but there is no one surgical technique or protocol that has been established to address each combination of prognostic factors. The aim of this commentary was to provide post-operative rehabilitation considerations for the treatment of rotator cuff repairs. We suggest using a spectrum of prognostic factors to determine a rehabilitation program suited to ensure structural and functional success, quickly and safely.

ABBREVIATIONS

ABD –	=	Abduction

AC –	=	Acromioclavicular
ASES –	=	American Shoulder and Elbow Surgeons
BMD –	=	Bone Mineral Density
CTA –	=	Computed Tomography Arthrography
DASH –	=	Disability of the Arm, Shoulder and Hand
DM –	=	Diabetes Mellitis
ER –	=	External rotation
FE –	=	Forward elevation
FI –	=	Fatty Infiltration
FPROM –	=	Full passive range of motin
GH –	=	Glenohumeral
MA –	=	Muscle Atrophy
MRI –	=	Magnetic Resonance Imaging
PROM –	=	Passive range of motion
RCR –	=	Rotator Cuff Repair
ROM –	=	Range of Motion
RR –	=	Risk Ratio
SANE –	=	Single Assessment Numeric Evaluation
SF-12 –	=	Short Form 12
SF-36 –	=	Short Form 36
ST –	=	Scapulothoracic
STAR –	=	Staged approach for Rehabilitation
US –	=	Ultrasound
WORC –	=	Western Ontario Rotator Cuff Index
SC –	=	Sternoclavicular

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CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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