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Anatomical and biomechanical framework for shoulder arthroplasty rehabilitation

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ABSTRACT

This article provides an anatomical and biomechanical framework for the postoperative management and progression of treatment for shoulder arthroplasty. The clinical relevance of normal shoulder anatomy, biomechanics, and pathomechanics related to this surgery is emphasized to provide the reader with an understanding of the rationale for treatment. We review the rehabilitation implications of surgical indications and technique for both traditional total shoulder arthroplasty and reverse total shoulder arthroplasty procedures with an emphasis on biomechanical considerations. Relevant factors that affect rehabilitation outcomes are discussed along with supporting evidence from the literature. Principles to guide and progress treatment are highlighted with a discussion on return to sports with the ultimate objective of providing a comprehensive approach for successful rehabilitation.

Introduction

The incidence of both conventional total shoulder arthroplasty (TSA) and reverse total shoulder arthroplasty (RTSA) procedures has been steadily increasing over the last several years, resulting in increased referrals for postoperative rehabilitation.[1] Shoulder arthroplasty is the most common joint replacement after hip and knee reported worldwide.[2,3] In the United States, the number of shoulder arthroplasty surgeries has increased by approximately 3000 cases every year over the past 12 years compared with an increase of 400 per year before 2004.[4] Increased incidence has also led to changes in implant design and surgical techniques. The goal of arthroplasty surgery is to restore or alter shoulder biomechanics and joint kinematics in the diseased and injured shoulder in an effort to decrease pain and improve function.

The purpose of this article is to describe the relevant anatomical and biomechanical principles and related evidence and discuss the clinical implications for rehabilitation to provide the clinician with the underlying rationale for treatment approach and progression. Successful outcomes of arthroplasty surgery depend on several factors, which include the preoperative condition, the design of the prosthetic implant, surgical skill, and the postoperative rehabilitation.[5] Progression of treatment is based on a comprehensive understanding of the underlying biomechanics, physiological healing process, and the individual's pre-existing pathology and tolerance for exercise and activity.

Surprisingly, despite a large body of evidence on shoulder arthroplasty outcomes, there are little published data on the effect of specific rehabilitation programs and approaches. Clinical outcome studies focus on the surgical approach and implant design and not on the contribution of postoperative therapy. Most studies acknowledge rehabilitation but lack details regarding specific exercises and time frames. Published postoperative guidelines are generally based on the original protocol developed by Hughes and Neer[6] with a range of modifications. Readers are referred to specific treatment guidelines and exercises detailed in multiple publications.[6-12] These guidelines are descriptive in nature, are not prospective, do not address differences in treatment approaches or advantages and disadvantages of existing protocols, and do not address the influence of therapy on outcomes.[2,7] Although it is clear that prospective studies are required to establish evidence-based rehabilitation, the purpose of this article is to emphasize the key anatomical and biomechanical considerations for restoration of function.

Shoulder anatomy, biomechanics, and function

Normal functioning of the shoulder is dependent on the interplay of motion, stability, and strength.[13,14] The shoulder functions to position the arm in space for a wide range of daily activities, such as

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using the hand to manipulate or grasp objects, lifting, reaching out in all directions, reaching overhead, and reaching behind the body.[15] The bones, joints, ligaments, and muscles function in a coordinated synchronized fashion that allows for pain-free functional motion of the shoulder.[14] Relationships between the joints, length tension relationships of muscles and soft tissue, as well as the timing and firing patterns of muscles are critical for effective function.[15-18] It is therefore essential for the clinician to understand how injury and surgery alter the biomechanics and kinematics in order to apply effective rehabilitation techniques and treatment progressions after shoulder arthroplasty.

The primary muscles and dynamic stabilizers of the shoulder can be divided into 3 primary groups. The scapulohumeral group includes the deltoid and rotator cuff muscles (supraspinatus, infraspinatus, teres minor, and subscapularis).[15,19] The axioscapular group comprises muscles that act on the scapula and includes the rhomboids, trapezius, serratus anterior, and levator scapula. The axiohumeral group includes the muscles that originate on the thorax and insert on the humerus and includes the latissimus dorsi and pectoralis major muscles.[15,19] The deltoid muscle is the primary abductor of the arm with supraspinatus contribution for initiation of movement.[13] The rotator cuff muscles collectively act to compress the humeral head in the glenoid fossa providing stability to the joint. Multiple muscles are activated synchronously to move the clavicle, scapula, and humerus to generate smooth movement of the arm. Retraction of the scapula is accomplished by the joint action of the trapezius and rhomboids.[15] Upward rotation of the scapula is achieved by a force coupling of the upper trapezius, lower trapezius, and serratus anterior muscles.[15] Scapular elevation is achieved through a force coupled action of the upper trapezius, levator scapulae, and rhomboids.[15] These force couples work together to rotate the scapula upward and contribute to the elevation of the arm.[15,19] The term scapula-humeral rhythm[19] refers to the 2:1 ratio of glenohumeral to scapulothoracic motion (Fig. 1). Full 180° elevation of the humerus cannot be achieved without 60° of upward rotation by the scapula on the thoracic spine.[19] The role of the rotator cuff is to stabilize the humeral head and counteract

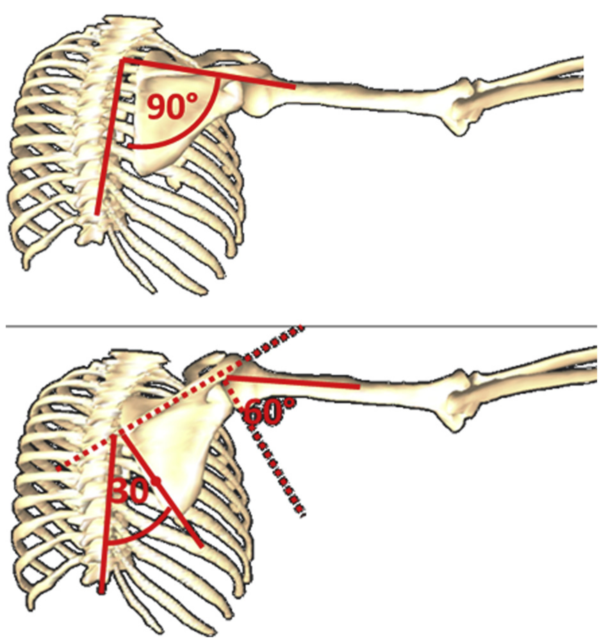

Fig. 1. Scapulohumeral rhythm. In a healthy shoulder joint, 90° of abduction of the humerus relative to the thorax (*top*) is achieved by 30° of scapular motion and 60° of glenohumeral motion.

antagonist moments from the 3 prime shoulder movers (deltoid, pectoralis major, and latissimus dorsi)[16] at multiple shoulder angles.[20] The supraspinatus compresses, abducts, and generates a small external rotation torque peaking between 30° and 60° of elevation.[16] In the absence of this check, the humeral head translates superiorly during humeral elevation resulting in impingement.[14,16] With rotator cuff pathology, altered kinematics and muscle activity are present,[21] and superior humeral head translation increases and subacromial space decreases.[22] In conditions such as osteoarthritis, cartilage degeneration and a collapsed head further alter the joint kinematics. The goal of conventional TSA is to restore stability, motion, strength, and smoothness; critical characteristics of a healthy shoulder joint.[23] This is accomplished by replacing the humeral head and glenoid with prosthetic implants that are designed to recreate the original anatomy. In the presence of intact rotator cuff and extrinsic shoulder muscles, a TSA is successful in restoring motion and improving function.

Total shoulder arthroplasty

Indications

TSA is indicated for complex humeral head fractures, advanced osteoarthritis, or rheumatoid arthritis that results in persistent pain or impairment with loss of function despite all conservative measures. TSA is contraindicated in cases of rotator cuff insufficiency, deltoid paralysis, or infection. In addition, TSA may not be indicated in patients who are unable or unwilling to participate in the extensive rehabilitation required after the procedure.[24]

Surgical overview

A thorough understanding of the surgical procedure and implant design is required to ensure proper protection of healing structures. TSA (Fig. 2) is usually performed via a deltopectoral approach to expose the glenohumeral joint.[8,24] An alternate and less common technique is the anterior approach where the deltoid is split, allowing for better glenoid exposure. An interscalene regional block is performed in the beach chair position, range of motion is assessed, and a deltopectoral incision is made to retract and/or release the pectoralis major. The short head of the biceps, coracobrachialis, and pectoralis minor are retracted, and the coracoacromial ligament is released.[24] To access the glenohumeral joint, the subscapularis must be released from its insertion on the lesser tuberosity. Violation of the subscapular tendon has serious ramifications for postoperative treatment, demanding vigilant protection of the healing tendon. Once the shoulder joint is dislocated, the humeral head along with any diseased bone and osteophytes are removed, and the implant is selected to be fit. Recent advances to prosthetic design include modular components that allow for trial components to be fit for size. Sizing of the humeral head is important to balance stability with range of motion.[24] Intraoperative assessment of prosthetic size is determined by several factors, including lateral humeral head offset, rotator cuff tissue tension, intraoperative range of motion, and stability of the shoulder. After the correct size is determined, the implant components (a titanium alloy stem, humeral head, and polyethylene glenoid) are inserted, and the humeral head and glenoid morphology are restored for the best balance of stability and range of motion.[24] New systems are introducing a metal back glenoid that is fixed with screws to the glenoid. The polyethylene cup is then inserted to the metal back. Any significant changes in the size of the humeral head or length of the stem could alter the length of the rotator cuff, potentially leading to shoulder impingement, dysfunction, and ultimately failure of the procedure.[14] Surgical

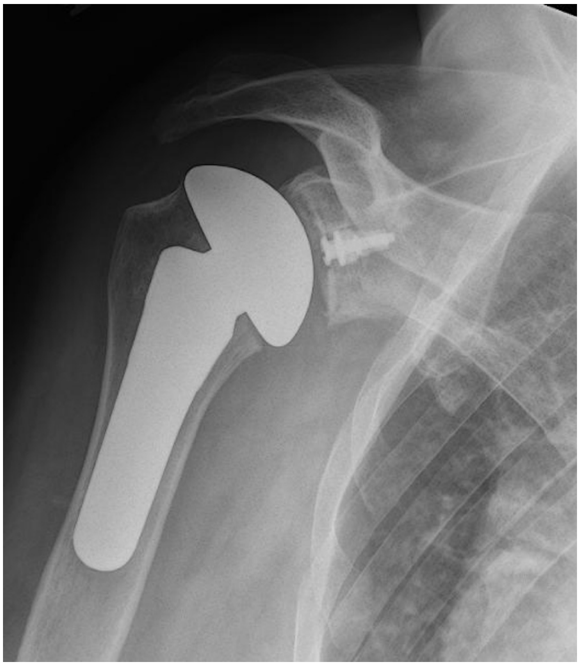

Fig. 2. Radiograph depicting traditional total shoulder arthroplasty (frontal view).

expertise with the technical aspects of the procedure is thus critical to a successful outcome. Once the implant is inserted and properly secured, the subscapularis tendon is repaired, and the incision is closed.

Application to rehabilitation

Rehabilitation plays an important role in contributing toward successful outcomes because of the surgical soft tissue reconstruction. Careful attention must be paid toward factors that affect both the progression of rehabilitation and overall outcomes. These factors include protecting repaired structures, avoiding positions that lead to instability, and gradual return to activity, sports, and work.

Postoperative treatment is dependent on the subscapular tendon repair technique. Protection of the subscapularis is critical for a successful outcome because of the importance of this muscle in shoulder function and stability.[8] Recent computational modeling studies have demonstrated how a deficient subscapularis after TSA contributes to shoulder instability. In the presence of a deficient subscapularis, the infraspinatus muscle force is decreased, which in turn induces a compensatory reaction from the supraspinatus and deltoid resulting in superior migration of the humeral head leading to instability.[25]

Protection of the subscapularis muscle is essential to maintain the integrity of the healing tendon and avoid dislocation.[26-28] For this reason, early rehabilitation after TSA emphasizes protection of the repaired structures and early protected range of motion exercises with a gradual progression of strengthening and functional activities.[7,8] This is accomplished by wearing a shoulder immobilizer or sling for 4-6 weeks postoperatively and limiting external rotation to prevent stress to the healing tendon. Early movement is performed in the plane of the scapula to limit tension on the capsule by maintaining a more centered position of the humeral head in the glenoid.[29] Early external rotation may be performed in a safe range, although active internal rotation such as reaching behind the back is contraindicated for the first few weeks to further protect the stability of the joint. Isometric rotator cuff strengthening is generally permitted by 4-6 weeks postsurgery and is guided by the healing subscapularis tendon. Treatment continues to progress with careful attention to joint stability.[8,29] Early strengthening begins with scapular stabilization exercises, particularly protraction and retraction to activate the lower trapezius and serratus anterior. This allows for early contraction of force coupled movement without stressing the glenohumeral joint.[30] Submaximal rotator cuff activation is also performed in a safe position. The ability to maintain control of the arm is constantly assessed and used to guide treatment via specific exercises to promote joint stability by strengthening the joint stabilizer muscles. This can be performed with various levels of resistance in the neutral position. By variably loading during isometric exercise, force is transmitted through the joint and scapulothoracic muscles without glenohumeral motion, thus protecting the stability.[30] As treatment progresses, gradual return to overhead activities is introduced. Repetitive overhead activity that is introduced too early can place mechanical demands on the implant that can ultimately lead to failure of the fixation with loosening between the bone cement interface and the cup.[14] In patients with an intact rotator cuff, functional overhead range of motion (at least 140°) is expected with full return to overhead functional activities.[7]

Factors affecting outcomes

The ultimate goal of rehabilitation is to maximize functional outcomes. Although overall successful outcomes have been reported after TSA using various assessment tools,[31-34] expectations and outcomes differ based on the pre-existing pathology. Defining and setting realistic expectations that are based on the individual clinical condition at the onset of the rehabilitation process contributes to overall patient satisfaction and to achieving realistic results. Henn et al[35] developed an expectations survey specific for shoulder arthroplasty that has been used to quantify and compare patient expectations with satisfaction after surgery. This tool is designed to be used preoperatively to manage expectations and patient satisfaction.

Factors that may affect outcome include the pre-existing pathology and extent of joint and soft tissue damage. Other factors that contribute to differences in outcomes and guide the treatment progression are whether the procedure was performed for a fracture or osteoarthritis, whether the patient had a pre-existing loss of range of motion, rotator cuff disease, muscle atrophy, muscle imbalances, neurologic issues, or postural deformities such as a thoracic kyphosis. Familiarity with both the pre-existing condition and reported outcomes for varying diagnostic groups assists the clinician in establishing realistic goals for treatment. Outcomes after traditional shoulder arthroplasty in patients with primary osteoarthritis are reported as highly successful for pain relief, self-reported patient satisfaction, and restoration of function and range of motion.[36,37] One study reported on a series of 94 cases, with a mean increase of 69° of elevation to 133° and an increase in Constant-Morley scores to 93.7%, with 93.9% of patients reporting high satisfaction with the surgery,[37] and only 7 patients requiring revisions. Successful outcomes are also reported for patients with rheumatoid arthritis who underwent a traditional shoulder arthroplasty, although outcomes are more moderate compared with those reported in the osteoarthritis studies. In a series of 58 patients, 37 were available for follow-up, and 29 reported moderate pain relief, and an average increase of range (53°-75°) with moderate improvements in function and several complications including implant loosening.[38] Complicating factors in this patient population include tissue quality, bone stock, and the general condition of the patient. In rheumatoid patients, the primary indication for shoulder arthroplasty is for pain, and progression of exercises is slower and more gradual. Outcomes reported for shoulder arthroplasty after proximal humeral fractures or malunions are even more variable due to the many confounding variables.[39,40] In one study of 27 patients reported range of motion for shoulder elevation increased from 41° to 88° and pain decreased.[39] A second study reported on a cohort of 50 patients with an increased shoulder elevation range of 65°-102°.[40] These studies suggest that range of motion outcome is not as good after TSA for humeral fractures, indicating that rehabilitation should progress slowly and gradually. Patients who undergo TSA with pre-existing rotator cuff insufficiency or rotator cuff arthropathy do not have good outcomes and are generally not considered good candidates for TSA. Without a functioning rotator cuff, the prosthesis will translate superiorly and eventually cause loosening of the components.[41] Rotator cuff arthropathy as described by Neer et al,[42] in which there is a massive cuff tear, osteoporotic collapse of the humeral head, and an alteration of biomechanics, leads to subacromial impingement eroding the coracoacromial ligaments and acromioclavicular joint.[42] For these reasons, a TSA is not recommended for patients with rotator cuff arthropathy, and an RTSA is considered a better option.

Reverse total shoulder arthroplasty

Indications

For patients who are not candidates for a TSA because of rotator cuff insufficiency or rotator cuff arthropathy, the RTSA may be indicated. In the healthy shoulder or TSA, the rotator cuff muscles provide dynamic shoulder stability via compressive forces to the joint (Fig. 3A). The glenohumeral joint is balanced anteriorly by the subscapularis and posteriorly by the infraspinatus and teres minor. The joint is further balanced by the compressive force of the supraspinatus that counteracts the pull of the deltoid by centering the humeral head.[16,43,44] This normal force couple is disrupted in the rotator cuff insufficient shoulder. As a result, the unopposed deltoid loses its rotational torque and displace the humeral head superiorly (Fig. 3B) with attempted forward elevation and abduction leading to the classic shoulder shrug posture.[16]

Surgical overview

The RTSA is designed to compensate for this change in joint mechanics by using a reverse ball and socket design. An RTSA uses an inverted biomechanical design compared with the traditional shoulder arthroplasty. In the reverse arthroplasty, the glenohumeral components are reversed replacing the glenoid with a baseplate and glenosphere, and the humeral head is replaced by a shaft and concave cup (Fig. 4). As a result, the center of rotation shifts medially. This alteration increases the deltoid moment arm resulting in improved torque and ability to raise the arm by recruiting more anterior and posterior fibers for flexion and abduction (Fig. 5).[16,43] This allows the deltoid to initiate shoulder abduction in the absence of a supraspinatus tendon resulting in improved motion and increased function. Additionally, the teres minor muscle which is inactive in a normal shoulder during elevation, contributes to the stability in RTSA by providing a balancing action to the pulling action of the deltoid.[45] Implant design and surgical techniques are constantly changing with efforts to improve and maximize outcomes. Significant variations in deltoid muscle moment arms as a result of humeral component offset changes have been reported in RTSA with larger anterior and lateral deltoid moment arms.[46,47] The variation in deltoid moment arms has implications for possible enhancement of deltoid moment arm function by changing the humeral offset position on a patient-specific basis. Advances in computational 3-dimensional musculoskeletal modeling of the shoulder are allowing for development of customized patient-specific implant design and patient-specific instrumentation for atypical presentations. The surgical approaches most commonly used are the deltopectoral approach (used for TSA and described previously) and the superior approach. The superior approach is facilitated by the exposure of the humeral head by the deficient rotator cuff. This approach allows for partial preservation of the subscapularis contributing to greater post-operative stability and earlier rehabilitation.[8,48]

Application to rehabilitation

Multiple factors affect patient outcomes after RTSA, including the pre-existing pathology, implant design and placement, quality of the remaining soft tissue, quality of the rehabilitation, and overall compliance with rehabilitation. The function of the shoulder depends greatly on the soft tissue tension, which is set by the

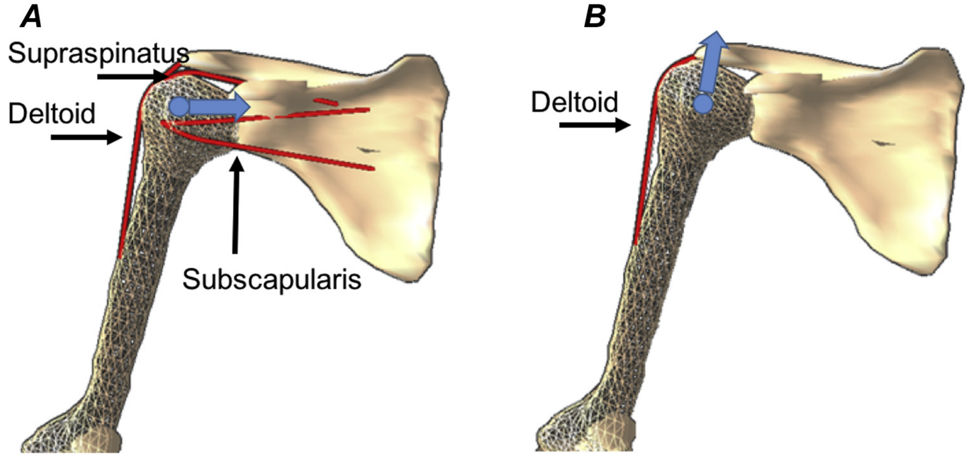

Fig. 3. (**A**) In a healthy shoulder (*left*), the deltoid and supraspinatus share the load where the action of the latter helps the resultant force compress the humeral head against the deltoid (*blue arrow*). (**B**) In the absence of the rotator cuff muscles, the unopposed deltoid force changes direction and increases the superior force causing the humerus to shift superiorly (*blue arrow*). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

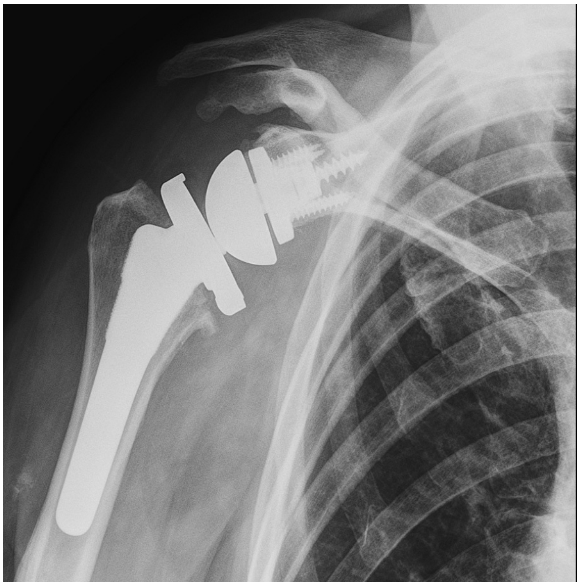

Fig. 4. Radiograph depicting reverse total shoulder arthroplasty (frontal view).

surgeon with the choice of prosthetic components used.[16,26,49] Deltoid tension is affected by the design of the reverse prosthesis, which distalizes and medializes the arm.[16] The optimal placement of the baseplate has been debated, but it is widely accepted that an inferior placement helps minimize impingement and glenoid notching.[16,49] In a more lateralized design, the deltoid moment arm is reduced, which results in increased recruitment of fibers, thus generating greater force.[16] Other factors including the size of the glenosphere, tilt, offset, and humeral neck-shaft angle contribute to motion and function and should be taken into account.[50] Preoperative external rotation deficit is another important factor that affects outcome. In patients with a severe deficit, a latissimus dorsi or teres major transfer is often considered.[8,51]

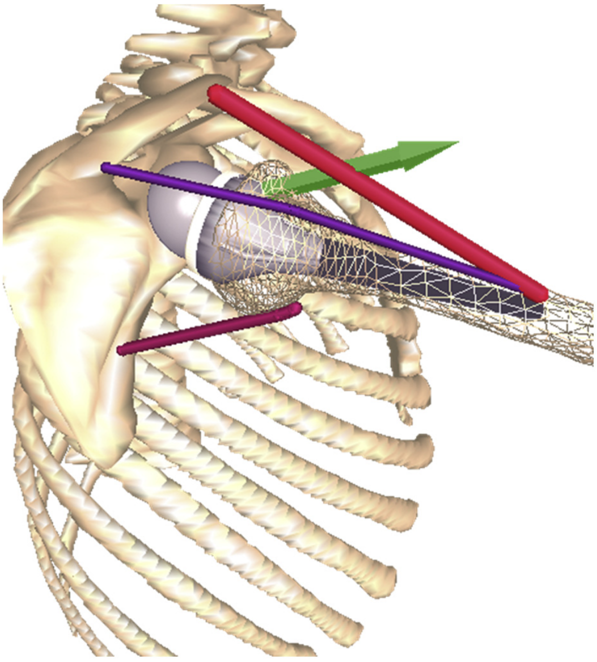

Fig. 5. Biomechanics of reverse total shoulder alter the deltoid moment arm for increased torque. Green arrow represents the combined action force of the deltoid and teres minor muscles. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

RTSAs are at a higher risk of dislocation than TSAs. The risk is even higher with a combined latissimus transfer.[8,51] To minimize the risk of dislocation, positions of internal humeral rotation and adduction are avoided in the early postoperative period, especially in combination with shoulder extension. In this position, the prosthesis is vulnerable to anterior and inferior dislocations.[52] Immediately after RTSA, an immobilization period ranging from 2-6 weeks is indicated before initiation of passive shoulder range of motion exercises. The immobilization period is dependent on the condition of the patient preoperatively, muscle and tendon quality, and overall fitness level. Positions such as tucking in a shirt or reaching behind the back are also generally avoided for at least 12 weeks. The RTSA is most stable in a position of approximately 30° of external rotation.[53]

A gentle gradual progression of deltoid and scapular strengthening exercises is key for successful rehabilitation in this population. Deltoid strengthening exercises are generally safe at approximately 6 weeks postsurgery.[52] Gentle deltoid and scapular strengthening can be initiated at that time and progressed according to patient tolerance. Recent studies have shown much greater scapular movement and a smaller scapulohumeral rhythm after RTSA than is seen in normal shoulders, although this has been found to vary greatly.[54,55] Particular attention to strengthening the periscapular muscles can help facilitate the increased demands for scapular movement and avoid complications associated with increased scapulothoracic movement, such as periscapular muscle pain, subscapular bursitis, acromioclavicular joint pain, and scapular spine stress fractures.[56] After RTSA, the change in kinematics results in larger flexion moment arms of the anterior deltoid and superior pectoralis major compared with a healthy shoulder, and rehabilitation is focused on strengthening these muscles to improve shoulder flexion.[16,57] Because most current designs limit external rotation, improving active external rotation is a challenge in rehabilitation. The posterior deltoid has been reported to activate external rotation with the shoulder in abduction in vitro.[16,57] Rehabilitation exercises in this position have been advocated to improve function.[16]

Close monitoring of patients' tolerance for activity is important during the strengthening phase, as the high amount of deltoid force generated across the acromion can lead to an increased risk of acromion stress fractures during this phase.[8,58] If pain develops, the shoulder should be assessed to rule out an acromion stress fracture. Education to avoid sudden jerking, lifting, or pushing motions is critical. These motions are contraindicated indefinitely after this procedure. Higher repetition with lighter resistance is preferred over lower repetition with high resistance in this patient population. Formal rehabilitation is continued for 4-6 months after surgery with the goal of achieving 120° of active elevation, functional external rotation of 30° with a 15-pound lifting limit bilaterally. In shoulders with residual rotator cuff function, a quicker progression is indicated. Normal range of motion is not expected after a reverse total shoulder replacement. Active elevation of 105°-120° is considered a functional and good outcome.[52]

Factors affecting outcomes

Clinical outcomes in RTSA vary according to pre-existing conditions and assessment methods.[59,60] Outcomes have been shown to correlate with pre-existing conditions. RTSA performed for primary osteoarthritis has better reported outcomes than RTSA performed in post-traumatic cases or after previously failed arthroplasties.[60] Younger patients who underwent RTSA had higher functional outcomes (Constant-Murley 54.3), active elevation (56°-121°) and lower complication rates than those performed in older patients.[61] The most common reported complications in RTSA have been reported recently by Bohsali et al[62,63] and include instability, periprosthetic fracture, infection, component loosening, neural injury, acromial and/or scapular spine fracture, hematoma, deltoid injury, rotator cuff tear, and venous thromboembolism.

Return to sports after TSA and RTSA

With the increased incidence and indication for shoulder arthroplasty surgery, particularly in younger individuals, patients are expressing expectations to return to sports and active activities.[35,64] Henn et al[35] reported greater expectations associated with younger patients. Improvements in implant component design and surgical technique have contributed to the ability to return to recreational sports depending on the condition of the patient preoperatively. These expectations influence the later phase of rehabilitation, shifting the emphasis to focus on return to a range of sports-related activities. Bulhoff et al reported on a cohort of 154 patients after TSA. Patients who participated in sports and were active during the 5 years before surgery ($n = 105$) reported high return to a wide range of sports and active activities, including skiing, tennis, golf, swimming, and gardening. Not surprisingly, the patients who did not participate in sports ($n = 49$) reported a very low return to sports rate.[65] In a recent review, Liu et al[64] reported an overall return to prior level of play of 85%, with a 92% return after TSA and 78% return after RTSA. Sports subgroups include contact sports, non–contact-high load sports, non–contact low load sports, and non–upper extremity sports with a risk of falling. Surgeons vary in their attitude toward return to sports participation after TSA and even more so after RTSA.[66] They are generally more permissive about return to non–contact low load sports, such as cycling, yoga, swimming, and golf, and vary widely on return to non–contact high load sports, or non–upper extremity sports with the risk of falling.[67,68] Although there is limited research and consensus by surgeons, the desire to return to sports and an active lifestyle will continue to increase as the popularity of these procedures continues to grow. Patients with an active lifestyle and high level of fitness before the procedure will have a higher likelihood of returning to some of those sport than those who were not active.[66]

Conclusion

Scientific and biomechanical principles are important factors to consider in the selection and progression of rehabilitation approach after both TSA and RTSA. Rehabilitation specialists should take into account the unique biomechanical changes that occur after both TSA and RTSA as they relate to the prosthesis design, surgical technique, changes in the joint, soft tissue, and the preoperative condition of the patient. Integrating these principles along with existing evidence guides effective treatment. Future prospective studies should investigate the contribution and differences of specific rehabilitation approaches to the outcomes after shoulder arthroplasty. As these procedures become more common, improving surgical components, surgical techniques, and improved customized rehabilitation by knowledgeable specialists should allow patients to continue to achieve higher functional levels.

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Quiz: #489

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#1. It is critical to protect the repair of the ______________ in devising the rehab plan
  a. suprascapular nerve
  b. deltoid
  c. posterior cuff
  d. subscapularis

#2. Normal shoulder kinematics involve
  a. secondary activation of the rotator cuff
  b. primary activation of the rotator cuff
  c. a force couple combining activation of the deltoid and the rotator cuff
  d. a force couple combining activation of the deltoid and the lower trapezius

#3. A reverse shoulder arthroplasty employs
  a. a convex element which is affixed to the scapula and articulates with a relatively shallow proximal humeral element
  b. a convex proximal humeral element
  c. a deeply concave proximal humeral element which articulates with an intact glenoid
  d. an externally rotated proximal humeral element and an internally rotated glenoid element

#4. In order to reduce pain and increase function shoulder arthroplasty attempts to
  a. correct articular cartilage defects
  b. restore proper biomechanics and joint kinematics
  c. denervate the glenohumeral joint
  d. partially fuse the glenohumeral joint

#5. The incidence of shoulder arthroplasty has increased significantly in the past several years
  a. false
  b. true

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