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Rehabilitation Following Total Shoulder Arthroplasty

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CLINICAL COMMENTARY

Total shoulder arthroplasty (TSA) is a standard operative treatment for a variety of disorders of the glenohumeral joint. Patients, who have continued shoulder pain and loss of function in the presence of advanced joint pathology, despite conservative management, are often managed by undergoing a TSA. The overall outcomes that are reported after surgical intervention are quite good and appear to be primarily determined by the underlying pathology and the tissue quality of the rotator cuff. The current Neer protocol for postoperative TSA rehabilitation is widely used and based on tradition and the basic science of soft tissue and bone healing. The purpose of this paper is to review the indications for TSA, focusing on the underlying pathologies, and to describe the variables that impact the rehabilitation program of individuals who have had a TSA. A postoperative TSA rehabilitation protocol and algorithm, founded on basic science principles and tailored toward the specific clinical condition, are presented. *J Orthop Sports Phys Ther 2005;35:821-836.*

Key Words: *physical therapy, protocols, shoulder rehabilitation*

The first total shoulder arthroplasty (TSA) was performed by Jules Emile Pean in 1893 for the purpose of treating tuberculous arthritis of the shoulder.[68] Neer[81] developed a humeral prosthesis for the treatment of 4-part fractures in 1955, and in the mid-1970s he refined his prosthesis for the treatment of the degenerative humeral head.[82] TSA is a standard treatment intervention for patients with underlying advanced joint pathology who have persistent pain and loss of function despite conservative management. These pathologies include osteoarthritis (OA),[7,13,30,32,39,41,43,44,64,71,74,82,86,88,89,100,101] rheumatoid arthritis (RA),[6,34,35,38,52,61,64,76,91,102,106] cuff tear arthropathy,[5,33,64,94,95,107,111] osteonecrosis,[26,48,49,64,70,79] and fractures of the humeral head.[2,3,6,21,42,62,69,85,90,93] Over the last 25 years, surgical techniques and prostheses have advanced greatly. However, there is still considerable variability in surgical techniques, particularly the use of cement for fixation and the type of prosthesis. Despite these significant variations, the overall reported outcomes for patients that have undergone TSA are good.[31,49,64,99,104] Self-assessed health status reports of individuals who have undergone TSA are comparable to those of individuals who have undergone a total hip arthroplasty or coronary artery bypass graft.[11]

In the early 1990s approximately 5000 TSAs were performed in the United States annually.[108] The success of a TSA procedure is predicated on several factors, including prosthetic design, etiology and severity of the underlying pathology, surgical technique, and postoperative rehabilitation.[34] Many factors have an impact on the outcome of patients who have had a TSA; they include preoperative health status, preoperative shoulder function, age, gender, and social environment.[22,32,37] To ensure optimal relief of pain and restoration of function, it is imperative to integrate preoperative, intraoperative, and postoperative factors when planning rehabilitation after TSA. Unfortunately, many of the published studies on TSA focus on surgical complications and have not specifically assessed functional outcomes or described in detail postoperative rehabilitation.

The purpose of this paper is to outline how underlying pathologies impact the rehabilitation program following TSA, with the intent to optimize functional outcome. Maybach and Schlegel[75] support the notion that the rate of progression for a patient following TSA should be based on underlying pathology in conjunction with the type of surgical technique used and the patient's overall tolerance to exercise and activity. A better understanding of these factors should enable the physical thera-

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pist to tailor a postoperative rehabilitation protocol to maximize recovery of function.

UNDERLYING PATHOLOGY

Outcome studies following TSA tend to focus on the longevity of the prosthesis, the patients' report of pain, and the amount of range of motion (ROM) gained as compared to preoperative measures. Most studies investigate outcomes for a group of patients with a specific underlying pathology. Although there are a large number of studies[6,13,21,26,30,32,34,35,38,39,41-44,48,49,52,61,62,71,74,76,79,82,85,86,88,90,91,93,95,100-102,106] that report outcomes for patients following TSA, these studies use varied assessment tools, primarily consisting of patient-reported surveys of shoulder function and general health status questionnaires. Impairments, which commonly only include ROM measures, are also not reported in a consistent manner. Consequently, it is difficult to critique whether differences in outcomes across studies are due primarily to the underlying pathology, surgical approach, postoperative management, or differences in which outcomes are measured. There are no universally accepted functional outcome measures for TSA.

Osteoarthritis

Pain relief after TSA for OA is very predictable. Most series report 90% to 95% of patients to be eventually pain free postsurgery.[6,16,22,64,82,89,104] TSA (Figure) is the most successful intervention for pain relief and restoration of function in patients with severe shoulder OA who have failed conservative treatment consisting of activity modification, medication, and physical therapy.[18] Patients with severe OA, which is typically characterized radiographically by joint-space narrowing, the formation of osteophytes, cystic changes on the humeral head and glenoid, subchondral bone sclerosis, and, at times, loose bodies, very rarely have rotator cuff tears.[84] The primary operative concerns in patients with OA are the severity of glenoid wear and the amount of capsular contracture. Quite frequently these patients have significant capsular contractures[97] and surgical releases are needed to restore motion and optimize function.

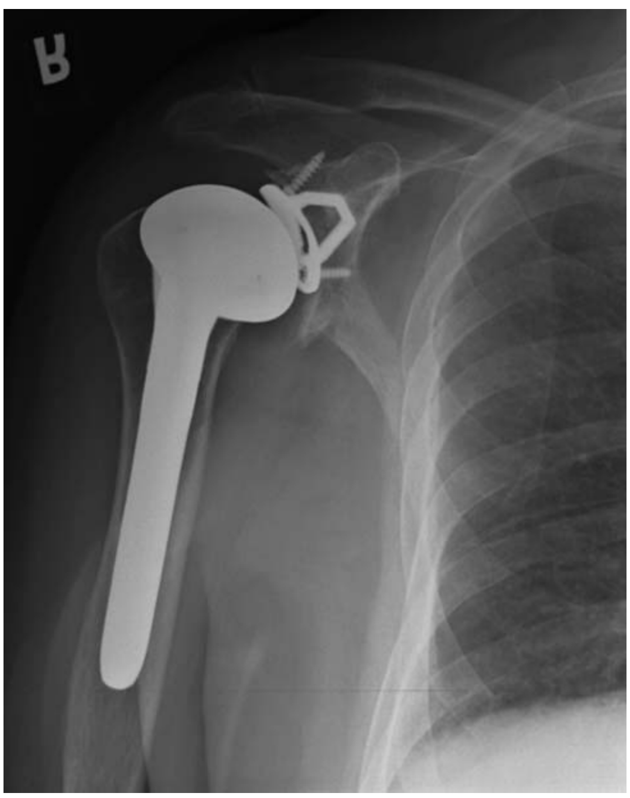

FIGURE. Anterior/posterior shoulder radiograph; right total shoulder arthroplasty of a patient who had severe osteoarthritis.

In patients with OA secondary to recurrent instability/dislocations the soft-tissue–related pathology of the joint capsule needs to be carefully considered. Often a loose joint capsule is found as the result of recurrent instability. However, in some individuals the joint capsule can be excessively tight as the result of previous surgery and/or the healing response from a previous injury. Those individuals who have tightness of the capsule, musculature, and ligamentous structures in the presence of OA typically require a complete surgical release of the capsule.

Levy et al[64] report that with cementless arthroplasty, using surface-replacement–type prosthesis, subjects with primary OA had raw Constant scores[24] of 93.7%, while subjects with posttraumatic humeral head fractures had scores of 62.7%, and patients with rotator cuff pathology had a score of 61.3%. The Constant score is based on a simple assessment of shoulder function that allows for individual-parameter assessments to be compared to an overall 100-point scoring system; the closer the value is to 100% the better functional status is per patient report. The mean active shoulder forward flexion for subjects at an average of 6.8 years postoperatively was 133° for those individuals who had primary OA and 73° for those who had rotator cuff arthropathy. These results demonstrate a difference in outcomes between these 2 subject groups attributed to the underlying pathology.

Goldberg et al[41] demonstrated substantial improvement in individuals treated with a TSA for OA. One hundred twenty-four patients were studied using the Simple Shoulder Test (SST)[67] at 7 different time intervals: preoperatively, and at 6 months, 1 year, 2 years, 3 years, 4 years, and 5 years postoperatively. The SST is a quick, subjective questionnaire consisting of 12 yes/no questions pertaining to shoulder function. It is scored by taking the total number of questions answered yes, divided by 12, to calculate a percentage. The higher the percentage the greater the reported shoulder function. Patients reported being able to complete (mean ± SD) 3.8 ± 0.3 of the 12 functional tasks required for the SST at their preoperative visit and (mean ± SD) 10.0 ± 0.4 at 5 years postoperatively. These results are very favorable in terms of functional improvement.

In a similar study, Matsen et al[72] evaluated 134 patients that had undergone a TSA. An improvement with SST scores from 4 (preoperative) to 9 at (mean ± SD) 3.4 ± 1.8 years postoperatively was reported. Improvement in the SF-36 general health survey score from 32 to 50 in the same time interval was also noted. These results are comparable and fairly consistent to those of Goldberg et al[41] primarily because both studies used the SST. However, the follow-up of (mean ± SD) 3.4 ± 1.8 years is a fairly short-term outcome that may not allow for sufficient assessment of clinically relevant potential postoperative complications. Wirth et al[108] state that an average follow-up of 3 years is not adequate to assess the occurrence of postoperative TSA complications. They found through a review of 41 studies that included 1858 patients who had undergone TSA from 1975 to 1995 that the average follow-up was only 3.5 years. They reported that there are no long-term studies of TSA comparable to those on lower extremity joint replacements. We agree that a follow-up of only 3 to 4 years does not allow for proper assessment of postoperative complications such as component loosening, glenohumeral instability, rotator cuff tear, and failure of the implant. We recommend postoperative follow-up of at least 10 years to allow for better assessment of prosthetic longevity, long-term rate of complications, and clinically relevant outcomes that occur after therapeutic intervention.

Patients that have undergone a TSA for OA should progress through a postoperative rehabilitation program that emphasizes early ROM and a gradual progression of strength and restoration of function. As long as an individual's rotator cuff is intact, the individual should expect to achieve overhead ROM that is functional (defined as greater than 140° of forward flexion). It has been reported that one needs 150° of forward flexion and abduction to comb one's hair without difficulty and a functional internal rotation reach behind one's back to thoracic level 6, in conjunction with shoulder external rotation of 55°, to be able to wash one's back without difficulty.[105] The table outlines common outcomes for patients who have undergone a TSA. Primary rehabilitation considerations for patients who have a TSA secondary to OA are to allow for adequate soft tissue healing and ensure proper glenohumeral mobility with passive ROM exercises prior to starting isometric strengthening exercises at 4 to 6 weeks postsurgery.[52] Patients with an intact rotator cuff should be able to easily transition from the initial passive ROM exercise phase of their rehabilitation to the early and advanced strengthening phases, as outlined in the protocol in Appendix 1.

Rheumatoid Arthritis

Patients with severe RA also benefit greatly from a TSA.[7,38,61,64,99,102] However, confounding factors, such as poor bone stock and soft tissue deficiencies, may complicate the surgical procedures,[83,102] affecting the extent to which a surgeon is able to achieve optimal reconstruction with a TSA. Patients with RA usually have excessive hypervascular synovial pannus that erodes the joint surfaces and the surrounding soft tissues. Also, there is a significant degree of osteopenia, which is the result of disuse and medications such as corticosteroids. Twenty to forty percent of patients with RA may also have a concomitant rotator cuff tear.[12] Such tears are usually due to erosive changes from the rheumatoid pannus and from the use of corticosteroids.[98] Repair of a rotator cuff tear in conjunction with the TSA procedure is a challenge for the surgeon and has very significant implications for postoperative rehabilitation as well.

Stewart and Kelly[102] state that previous studies have reported some early controversy or misgivings about the outcomes of unconstrained TSA in patients with RA. They reported that most of the previous research focused on short-term results and that longer-term results needed to be established. In their own series, they found rather high incidence of lucencies around the components (62% of the glenoid components, 57% of the humeral components, and 25% of both components together). The presence of lucency can indicate prosthetic loosening. But, in this study the presence of such lucencies did not lead to premature loosening, with only 8 of 37 components being loose at a mean follow-up of 9.5 years. The authors further reported that only 5 of 37 components in 3 shoulders lead to pain and declined functional status significant enough to warrant revision. They concluded that TSA for individuals with RA provided reliable long-term pain relief with ROM and functional improvements, which seems reasonable and justified. Unfortunately their study only measured 4 functional tasks to assess the patient outcomes. Had they used an outcome scale, such as the SST, their study could be better compared to others. The outcomes were primarily focused on the surgical results, specifically the incidence of loosening following TSA. This is very commonly found with most published studies of TSA for patients with RA.[61,64,65,102] Few studies effectively measure functional outcomes or postoperative rehabilitation of these patients.[38,76,106]

Often the primary indication for TSA for patients with RA is for pain control. The expectation of better ROM or function postsurgery is not appropriate. Typically ROM outcomes following surgery are much less than for those who had a TSA secondary to OA

(Table). Hence, these patients' progression through a postoperative rehabilitation program will be different than for the patient who had a TSA for OA, in which active overhead motion is expected. Stretching, joint mobilization, and ROM activities need to be more gradually progressed with the patient with RA, because of the probability of poor bone stock and poor soft tissue integrity. The progression of strengthening for patients with RA should focus more on regaining strength sufficient to perform functional activities below 90° of flexion, because overhead motion may not likely be achieved. These patients may not progress past the early strengthening phase on the protocol in Appendix 1.

Rotator Cuff Deficiency/Cuff Tear Arthropathy

Rehabilitation after TSA is clinically more challenging when the integrity of the rotator cuff is poor and clinical results are generally not as good as they are for those with an intact rotator cuff. An upward riding of the prosthetic humeral head secondary to the rotator cuff deficiency may contribute to the loosening of the glenoid component.[36] Hawkins et

TABLE. Reported outcomes of patients who have had a total shoulder arthroplasty based on underlying pathology.

Underlying Pathology	Number of Shoulders	Mean Active Flexion Range of Motion (°)	Mean Active Abduction Range of Motion (°)	Mean Active External Rotation (°)	Functional Score	Authors/Date
Osteoarthritis	33	133	113	55	94/100*	Levy et al 2001[64]
	37	147	‖	39	91/100†	Orfaly et al 2003[89]
	134	‖	‖	‖	75/100‡	Matsen et al 2000[72]
	124	‖	‖	‖	83/100‡	Goldberg et al 2001[41]
Osteonecrosis unspecified	4	133	118	81	‖	Levy et al 2001[64]
Osteonecrosis due to steroids	52	138	125	66	72/100†	Hattrup et al 2000[49]
Osteonecrosis due to trauma	46	107	86	49	66/100†	Hattrup et al 2000[49]
Rheumatoid arthritis	27	104	80	44	‖	Levy et al 2001[64]
	24	81	‖	51	§	Friedman et al 1989[38]
	37	75	‖	38	§	Stewart and Kelly 1997[102]
	140	90	‖	40	§	Barrett et al 1989[7]
Proximal humerus fractures	27	‖	88	38	‖	Antuna et al 2002[3]
	50	102	‖	35	‖	Antuna et al 2002[2]
	23	92	‖	27	‖	Norris et al 1995[85]
Cuff deficiency/ arthropathy	12	115	‖	41	‖	Arntz et al 1993[4]
	21	120	‖	46	‖	Williams and Rockwood 1996[107]
	16	100	‖	30	‖	Field et al 1997[33]
	33	91	‖	41	‖	Sanchez-Sotelo et al 2001[94]
	15	86	‖	29	22/35	Zuckerman et al 2000[111]
	8	73	64	47	613/100*	Levy et al 2001[64]
	14	88	‖	37	80/100†	Sarris et al 2003[95]

* Constant score (range, 0 to 100, with the higher the value the better functional status per patient report).
† American Shoulder and Elbow Surgeon's Shoulder Evaluation (range, 0 to 100, with higher score representing less pain and greater shoulder function).
‡ The Simple Shoulder Test (range, 0 to 100, with higher score indicating greater reported shoulder function).
§ Reported, but not with a standardized measure.
‖ Not Reported.
¶ University of California Los Angeles Shoulder Score (range, 3 to 35, with higher score indicating increased shoulder function).

al[50] concluded from their series of 65 patients followed over an average of 40 months that the underlying etiology of the disease process and the status of the rotator cuff are the best predictors of outcome for individuals treated with TSA.

Cuff tear arthropathy, which consists of severe humeral head collapse following massive tearing of the rotator cuff, has been described by Neer.[83,84] He proposed that inactivity following a massive tear of the rotator cuff results in instability of the humeral head and leakage of the synovial fluid, resulting in atrophy of the glenohumeral articular cartilage and osteoporosis and collapse of the humeral head, thus altering the glenohumeral joint biomechanics. This leads to subacromial impingement, which over time erodes the coracoacromial ligament and the acromioclavicular joint. Cuff tear arthropathy occurs when the soft, atrophic humeral head collapses. Neer estimated on his observation of 52 patients with cuff tear arthropathy over an 8-year period that cuff tear arthropathy would only develop in about 4% of patients who have a complete cuff tear.[84] Typically, patients that have developed a cuff tear arthropathy have an irreparable rotator cuff.

ROM and functional outcomes of patients with cuff tear arthropathy following humeral head replacement are typically less than for patients having TSA for OA; a return of forward flexion ROM of around 90° is typically the outcome for these patients.[64,94,95,111] Because of high rates of glenoid loosening, some feel that a TSA is contraindicated with an irreparable rotator cuff and that a hemiarthroplasty procedure to resurface the humeral side of the joint provides pain relief and is the preferred method of treatment.[4,33,94,95,107,110,111] Generally pain relief is good with this approach, although some patients still have pain from the unresurfaced glenoid. Unfortunately, because there is no rotator cuff, functional outcomes are somewhat unpredictable. Recently, the introduction of the reversed prosthesis, such as the Delta prostheses (Depuy, Inc, Warsaw, IN), has been reported as a potentially better treatment option for these patients.[28,57]

The indications for TSA for patients with cuff tear arthropathy may be similar to those with RA as the underlying pathology. Because the underlying pathology is similar to RA, the progression of these patients through a postoperative rehabilitation program should be somewhat similar to those who have RA.

Soft tissue healing time needs to be considered when progressing the patient who has had a rotator cuff repair in conjunction with a TSA. Stretching, joint mobilization, and ROM activities should be gradually progressed because the patient with cuff tear arthropathy may have poor bone quality and poor cuff integrity. In addition, the rotator cuff may or may not have been surgically repaired, based on the status of the rotator cuff tissue quality. Typically these patients do not have adequate tendon healing to withstand applied muscle forces generated by simply raising the arm until around 4 to 6 weeks postoperatively. At this point, resistance exercises of the rotator cuff are still not recommended, as tendon healing is insufficient for the forces generated during strengthening. Strengthening for the patient who has had a rotator cuff repair in conjunction with their TSA should not start before 10 to 12 weeks postoperatively. Animal studies of tendon healing[19,60,66,109] and empirical clinical observation suggest that by this point healing is generally considered sufficient to allow a gradual program of muscle strengthening. Once strengthening is started, it should focus on regaining functional movement and strength below 90° of shoulder elevation, because overhead motion will not likely be achieved. These patients may not progress past the early strengthening phase as outlined on the protocol in Appendix 1.

Furthermore, glenohumeral and scapulothoracic kinematics and soft tissue compliance should be sufficiently restored, so that a strengthening program can be safely initiated without irritating the rotator cuff. Certainly, this 10- to 12-week time frame needs to be adjusted based on the evaluation of the patient's original rotator cuff tear size, intraoperatively inspected soft tissue quality, and overall rehabilitation progress as specifically indicated by the quality of active movement and tolerance for exercise.

Osteonecrosis

The collapse of the articular surface of the humeral head can result from osteonecrosis and lead to painful degenerative changes.[25] Corticosteroid use, alcohol abuse, Caisson's disease, Cushing's syndrome, and systemic lupus erythematosus are potential causes for osteonecrosis.[25,27,53,56,58,63,78] TSA is frequently indicated for the treatment of osteonecrosis of the humeral head; however, functional outcomes following surgery vary, possibly based on the etiology of osteonecrosis.[49] Those individuals who have a TSA due to osteonecrosis from steroid use seem to have better ROM outcomes than those who have osteonecrosis from trauma (Table). Based on the potential variations in outcomes, a clinician that is devising the postoperative rehabilitation program for a patient who had a TSA due to osteonecrosis should take into account the underlying etiology.

Proximal Humerus Fractures

TSA is a reasonable treatment option for patients that have a nonunion[3] or malunion[2] of the proximal humerus. However, few reports[2,29,51,80,85] regarding functional postoperative outcomes exist. Antuna et al[3] found that patients who had significant functional limitations as the result of a nonunion humeral fracture which had failed internal fixation in the presence of severe osteoporosis and cavitation of the humeral head benefited from shoulder arthroplasty. Patient satisfaction was good, but mean active shoulder abduction was only 88° in their series of 27 subjects. This is consistent with Norris et al's[85] results of active mean shoulder flexion of only 92° following TSA for proximal humeral fractures in their series of 23 subjects. In another series Antuna et al[2] found that 50 subjects who underwent a TSA due to a malunion of a humeral fracture had a mean active elevation of 102° postoperatively.

Because little is known about the optimal functional outcomes of patients who have undergone a TSA for proximal humerus fractures, it is important for the treating therapist to have a good understanding of the underlying fracture type and how the patient's history of previous fracture management may impact their postoperative outcome. Though not widely researched, there appears to be a difference in outcome when TSA is done as the primary intervention for fracture, compared to delayed replacement after nonunion or malunion. This raises the question whether immediate shoulder replacement for the more severe/displaced proximal humerus fractures yield better results than if replacement is delayed.

Patients who undergo a delayed TSA following a proximal humerus fracture with nonunion or malunion often undergo the procedure for the same rationale as those with underlying RA or cuff tear arthropathy. Typically the ROM outcomes are less than for those who had a TSA for OA or osteonecrosis (Table). Hence, the progression through a postoperative rehabilitation program may be somewhat similar to those who have RA and/or cuff arthropathy. Stretching, joint mobilization, and ROM activities need to be gradually progressed, depending on the status of the soft tissues. Those patients who have had a proximal humerus fracture managed with a primary TSA with an intact cuff may be managed like those who had a TSA for OA. Close collaboration with the referring surgeon is recommended to establish an accurate prognosis.

SOFT TISSUE CONSIDERATIONS

Regardless of underlying pathology, operative soft tissue reconstruction is crucial for a good outcome following TSA. Soft tissue balancing at the time of surgery is the process of restoring the soft tissue anatomy to near-normal parameters, attempting to avoid either overtightened or insufficiently released structures so as to maximize joint function and stability.[55] The ability to reconstruct and balance the musculature, tendons, and joint capsule, along with the experience of the surgeon, are cited as critical factors in the result of TSA.[20,45,46,55,59,96]

Three specific operative factors regarding rotator cuff management have major impact on soft tissue balancing. The first is the technique used to take down the subscapularis to gain exposure of the glenohumeral joint, usually via a deltopectoral approach. The subscapularis and more importantly the underlying joint capsule are often severely contracted in patients with arthritic shoulders.[22] This contracture may require a release and/or lengthening to allow for adequate external rotation of the shoulder. Some have described the use of a Z-plasty lengthening technique, although the surgical author (P.J.M.) prefers to avoid this, as it makes the subscapularis quite thin and may predispose it to rupture postoperatively. The alternative to doing a Z-plasty is to do a medialization of the subscapularis insertion on the neck of the humerus.

A second factor that influences soft tissue balancing is the presence of a rotator cuff tear that requires repair. Small tears can be handled quite easily and are not expected to affect the outcome. On the other hand, the repair of massive tears leaves the rotator cuff under a great deal of strain, which increases the risk of rerupture of the cuff or excessive force on the glenoid, possibly leading to premature glenoid component loosening.[18] Soft tissue healing must be considered when determining when to progress strengthening. In general, strengthening should not start until 10 to 12 weeks postoperatively. As previously stated, animal studies[19,60,66,109] and empirical clinical observation suggest that by 10 to 12 weeks postoperative tendon repair healing is generally considered sufficient to begin a gradual program of muscle strengthening.

The last factor to consider regarding soft tissue balancing is the size of the prosthetic humeral head. Some have argued that a larger head can be used to increase rotator cuff tension and thus improve stability; however, that approach compromises ROM.[23,47] Improper sizing of the humeral head will lead to poor biomechanics of the shoulder and compromise ROM and function.[34,47,54] The surgical author (P.J.M.) prefers to perform an anatomic restoration of the glenohumeral joint. The goal is to restore the joint to its original state and to avoid oversizing the humeral head.

SURGICAL CONSIDERATIONS

When devising the surgical plan for a patient undergoing a TSA, a number of factors are considered in selecting the type and characteristics of the prosthesis to be used. Whether cement is used or not is dependent on the prosthetic system selected, underlying pathology, and quality of bone stock. Cement is often used with severe osteopenia. The position of the prosthetic components is critical for proper joint stability, prosthetic longevity, and amount of total pain-free ROM.[18] Consideration must be given to the neck shaft angle, humeral head retroversion, and humeral head size to properly fit the humeral component. The proper glenoid component placement is determined by restoring anatomical position of the glenoid as close to perfect as possible. The surgical author (P.J.M.) prefers to obtain a CT scan preoperatively to evaluate the degree of retroversion. The surgical goal is to restore version to neutral when placing the glenoid component, with neutral defined as perpendicular to the transverse (axial) axis of the scapular body. This placement is usually dependent on the consideration of the bony support available for the glenoid component.[23]

SUBSCAPULARIS DYSFUNCTION

Subscapularis dysfunction following TSA has recently been identified as a potential postoperative complication. Miller et al[77] reported on their series of 41 patients. At a mean follow-up of 1.9 years, shoulder internal rotation was assessed by the use of the lift-off[40] and belly-press[103] tests. Abnormal findings were found in roughly 66% of these patients. Diminished subscapularis function was identified in 92% of the 25 individuals with a positive lift-off test. In all cases, passive ROM was initiated on the first postoperative day for forward flexion and shoulder external rotation at 0° of abduction. External rotation ROM was limited to between 30° and 40°, based on the intraoperatively determined safe zone of the subscapularis. Gentle strengthening was initiated at postoperative week 6 and full resumption of activities was allowed between 3 and 4 months. More recently, to protect the tendon, our surgical group has been using a lesser tuberosity osteotomy to remove the subscapularis. Biomechanical testing has shown this to be twice as strong as soft tissue repairs and the surgical author has noted a very low incidence of subscapularis dysfunction postoperatively. Nevertheless, we believe that clinicians should be aware of the risk of subscapularis dysfunction following TSA. It may be the result of tendon pull-off, poor tissue quality, inappropriately progressed external rotation stretching/ROM activity, or oversized components leading to excessive tissue tension. Aggressive external rotation stretching and/or too vigorous internal rotation strengthening should be avoided.

REHABILITATION

Because TSA surgery primarily involves soft tissue reconstruction, a large factor in the success of the procedure is postoperative rehabilitation. It is widely reported that postoperative rehabilitation is crucial to the overall functional outcome of individuals that have undergone a TSA.[15,17,52] Overall recovery may take up to 1 to 2 years and outcomes are primarily based on the status of involved soft tissue.[18,41] Most rehabilitation programs for TSA are based on Neer's basic protocol.[52] There are very few reported references regarding this rehabilitation program and resulting functional outcomes. Most references are empirical descriptions of the rehabilitation program, as opposed to actual clinical trials assessing its effectiveness. Boardman et al[10] agrees that there is very "limited descriptions of postoperative rehabilitation programs" for TSA in the literature. Most published programs are simply protocols of specific exercises progressed at specific timelines from passive to active ROM, then to eventual strengthening. These protocols lack criteria beyond timelines for progression[15,17,75] rather than evaluation-based protocols, as suggested by Noyes et al.[87] In addition, none of these protocols address early scapular musculature activity. It is surprising to find such a small amount of literature on rehabilitation programs, especially because it has been frequently noted that the success of the procedure relies heavily on the soft tissue variables and the postoperative management. There is consensus among the surgical community regarding the importance of effective and appropriate postoperative rehabilitation management. Nearly every article in the literature about TSA states that the success of TSA is dependent upon rehabilitation. Charles Neer II has stated, "Shoulder replacement will fail without adequate rehabilitation."[14] Hughes and Neer[52] published the first TSA protocol in 1975. The experience of one of this paper's authors (L.E.A.), who worked closely with Dr Neer when his protocol was first developed, is that the progression of exercises and the timelines outlined in his 4 phases were continually modified based on the clinical presentation of the patient and their underlying pathology. This experience is not necessarily discussed or outlined in most published TSA protocols. The clinical experience of protocol modification based on clinical presentation and underlying pathology is the basis of much of the information offered in this manuscript.

Most programs appear strictly structured with regular supervision by the therapist and primary surgeon. However, Boardman et al[10] challenged this traditional treatment process by looking at the effectiveness of a home-based therapeutic exercise program following TSA. Overall, their results were reported to be quite favorable in that 70% and 90% of patients maintained ROM in forward flexion and external rotation, respectively, over a 2-year follow-up period. Average forward flexion was found to be 148° in the group with OA group and 113° in the group with osteonecrosis. One of their study's goals was to evaluate the standard rehabilitation program for TSA. Unfortunately, they only briefly discussed their overall postoperative protocol, which was stated to be based on the principles first outlined by Hughes and Neer in 1975.[52] Because a clear description of the protocol is not published, it would be difficult to reproduce their results. It appears from their very brief description of the postoperative program that patients primarily participated in an unspecified home exercise program and periodically had physical therapy visits, which appear to have consisted of learning their new exercises for the next phase of rehabilitation. Their ROM values are quite good compared to many other outcome studies. However, solely looking at ROM does not allow a comprehensive assessment of how well a patient did postoperatively or how effective the rehabilitation program was. There is no report of the quality of the patient's movement, what the pain level was, and what the functional outcomes were.

It is standard practice for patients to begin early (a few hours postoperatively in the hospital) passive ROM following a TSA. This has been established in literature from Brems,[14,15] Brown,[17] and Cameron.[18] However, other than consensus regarding early ROM, progression varies considerably. There are several published protocols[14,15,17,18] regarding the postoperative rehabilitation following TSA and, according to Brems,[15] this is an indication that there has not been one program established as most effective.

Typical protocols are not structured to accommodate for, and address, underlying pathology. Individuals who have been treated with a TSA, with or without rotator cuff pathology, will need to progress at a much different pace. As previously discussed, patients with severe RA, or who had a delayed or primary humerus fracture or cuff arthropathy as their underlying pathology, may have had a TSA for pain control with low expectations for ROM and/or function. Therefore, the protocol they follow should be different than that for the young patient with osteonecrosis who has a healthy rotator cuff and a high expectation to return to a high functional level.

We suggest that those patients with a concurrent repair of a rotator cuff tear and/or a TSA secondary to RA, a delayed or nonunion of a fracture, or cuff arthropathy should be progressed to the next phase of rehabilitation based on specified clinical criteria and not on typical postoperative time frames. Also, any postoperative rehabilitation program should be established with strong collaboration between the physical therapist and referring surgeon. The achievement of specific clinical criteria enable the surgeon, physical therapist, and patient to customize the postoperative course based on how the individual is progressing postoperatively, taking into consideration underlying pathology and possible comorbidities. Time frames on such protocols should be identified merely as an approximate guide for progression and not the progression criteria itself. Timelines should only be used to ensure that a clinician and patient are progressing to activities that are appropriately geared to the current postoperative state of healing.

The 3 protocols[15,17,18] previously mentioned in this review are broken down into 3 or 4 phases of recovery and use timelines for progression to the next phase. These phases are identified and described as passive ROM, active ROM, and strengthening phases. However, patients do not always progress clinically at the same rate delineated by the 3 or 4 phases of the protocol. In addition, none of these protocols include early scapular musculature stabilizer exercises. It is our opinion that early scapular stability work is crucial to the rehabilitation of a patient who has undergone a TSA. Both Brems[14,15] and Brown[17] agree that maximizing passive motion is the first major goal of therapy, followed by regaining strength, as the ability to restore strength is directly dependent on the available passive ROM.

In our clinic, we have chosen to use the SST and the American Shoulder and Elbow Surgeon's Shoulder Evaluation Short Form[9] because they have been found to have good reliability and fairly high responsiveness, as compared to other shoulder outcome tools.[8] They are very simple and quick for the subject and therapist to fill out. The SST has been demonstrated to be sensitive for various shoulder conditions as well as sensitive in detecting changes in shoulder function over time.[73] In addition, the SST has been found to correlate well with the University of California at Los Angeles Shoulder Score[1] and the Constant score.[92]

SUMMARY

There are multiple underlying pathologies that are most effectively managed with TSA. Clinical practice suggests that these different patient populations have vastly different outcomes in terms of pain relief, ROM, and, most importantly, function. This difference in underlying pathologies in conjunction with tissue-healing time frames should be the basis of any protocol or standard of care following TSA. Such consideration should provide an effective postoperative plan of care, which should allow patients to reach their maximum functional recovery. It is proposed that a standard of care that is tailored to each specific patient by considering the underlying pathology, with a focus on meeting specific impairment and functional criteria before progressing to the next stage of rehabilitation, will promote maximal functional recovery (Appendices 1 and 2).

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Appendix

APPENDIX 1

Total Shoulder Arthroplasty/Hemiarthroplasty Protocol

The intent of this protocol is to provide the clinician with a guideline of the postoperative rehabilitation course of a patient that has undergone a total shoulder arthroplasty (TSA) or hemiarthroplasty (humeral head replacement [HHR]). It is not intended to be a substitute for appropriate clinical decision making regarding the progression of a patient's postoperative course. The actual postsurgical physical therapy management must be based on the surgical approach, physical exam/findings, individual progress, and/or the presence of postoperative complications. If a clinician requires assistance in the progression of a patient postsurgery, the clinician should consult with the referring surgeon.

<u>Please note:</u> Patients with a concomitant repair of a rotator cuff tear and/or a TSA/HHR secondary to fracture or cuff arthropathy should be progressed to the next phase, based on meeting the clinical criteria (not based on the postoperative time frames) as appropriate in collaboration with the referring surgeon. The given time frames are an approximate guide for progression, achieving the clinical criteria should guide the clinician and patient through this protocol.

Joint Specific Outcome Measure

Upon the start of postoperative care the patient and therapist complete the Simple Shoulder Test and the American Shoulder and Elbow Surgeon's Shoulder Evaluation Short Form during their first ambulatory visit. These assessment measures are then completed every 30 days and upon discharge from physical therapy, in conjunction with routine re-evaluations to assist in assessing progress.

Phase I: Immediate Postsurgical Phase

Goals:
- Allow healing of soft tissue
- Maintain integrity of replaced joint
- Gradually increase passive range of motion (PROM) of shoulder; restore active range of motion (AROM) of elbow/wrist/hand
- Reduce pain and inflammation
- Reduce muscular inhibition
- Independence with activities of daily living (ADLs) with modifications, while maintaining the integrity of the replaced joint

Precautions:
- Sling should be worn continuously for 3 to 4 weeks
- While lying supine, a small pillow or towel roll should be placed behind the elbow to avoid shoulder hyperextension/anterior capsule stretch/subscapularis stretch
- Avoid shoulder AROM
- No lifting of objects
- No excessive shoulder motion behind back, especially into internal rotation (IR)
- No excessive stretching or sudden movements (particularly external rotation [ER])
- No supporting of body weight by hand on involved side
- Keep incision clean and dry (no soaking for 2 weeks)
- No driving for 3 weeks

<u>Postoperative Day 1 (in Hospital)</u>
- Passive forward flexion in supine to tolerance
- Gentle ER in scapular plane to available PROM (as documented in operative note), usually around 30° (attention: DO NOT produce undue stress on the anterior joint capsule, particularly with shoulder in extension)
- Passive IR to chest
- Active distal extremity exercise (elbow, wrist, hand)

- Pendulum exercises
- Frequent cryotherapy for pain, swelling, and inflammation management
- Patient education regarding proper positioning and joint protection techniques

Early Phase I (out of Hospital)
- Continue above exercises
- Begin scapula musculature isometrics/sets (primarily retraction)
- Continue active elbow ROM
- Continue cryotherapy as much as able for pain and inflammation management

Late Phase I
- Continue previous exercises
- Continue to progress PROM as motion allows
- Begin assisted flexion, abduction, ER, IR in the scapular plane
- Progress active distal extremity exercise to strengthening as appropriate

Criteria for progression to the next phase (II):
- Tolerates PROM program
- Achieves at least 90° PROM flexion
- Achieves at least 90° PROM abduction
- Achieves at least 45° PROM ER in plane of scapula
- Achieves at least 70° PROM IR in plane of scapula measured at 30° of abduction

CLINICAL COMMENTARY

Phase II: Early Strengthening Phase

(Not to begin before 4 to 6 weeks postsurgery to allow for appropriate soft tissue healing.)

Goals:
- Restore full passive ROM
- Gradually restore active motion
- Control pain and inflammation
- Allow continue healing of soft tissue
- Do not overstress healing tissue
- Re-establish dynamic shoulder stability

Precautions:
- Sling should only be used for sleeping and removed gradually over the course of the next 2 weeks, for periods throughout the day
- While lying supine, a small pillow or towel should be placed behind the elbow to avoid shoulder hyperextension/anterior capsule stretch
- In the presence of poor shoulder mechanics avoid repetitive shoulder AROM exercises/activity against gravity in standing
- No heavy lifting of objects (no heavier than coffee cup)
- No supporting of body weight by hand on involved side
- No sudden jerking motions

Early Phase II
- Continue with PROM, active assisted range of motion (AAROM)
- Begin active flexion, IR, ER, abduction pain-free ROM
- AAROM pulleys (flexion and abduction), as long as greater than 90° of PROM
- Begin shoulder submaximal pain-free shoulder isometrics in neutral
- Scapular strengthening exercises as appropriate
- Begin assisted horizontal adduction
- Progress distal extremity exercises with light resistance as appropriate
- Gentle glenohumeral and scapulothoracic joint mobilizations as indicated
- Initiate glenohumeral and scapulothoracic rhythmic stabilization
- Continue use of cryotherapy for pain and inflammation

Late Phase II
- Progress scapular strengthening exercises

Criteria for progression to the next phase (III):
- Tolerates PROM/AAROM, isometric program
- Achieves at least 140° PROM flexion
- Achieves at least 120° PROM abduction
- Achieves at least 60° PROM ER in plane of scapula
- Achieves at least 70° PROM IR in plane of scapula measured at 30° of abduction
- Able to actively elevate shoulder against gravity with good mechanics to 100°

Phase III: Moderate Strengthening

(Not to begin before 6 weeks postsurgery to allow for appropriate soft tissue healing and to ensure adequate ROM.)

Goals:
- Gradual restoration of shoulder strength, power, and endurance
- Optimize neuromuscular control
- Gradual return to functional activities with involved upper extremity

Precautions:
- No heavy lifting of objects (no heavier than 3 kg)
- No sudden lifting or pushing activities
- No sudden jerking motions

Early Phase III
- Progress AROM exercise/activity as appropriate
- Advance PROM to stretching as appropriate
- Continue PROM as needed to maintain ROM
- Initiate assisted shoulder IR behind back stretch
- Resisted shoulder IR, ER in scapular plane
- Begin light functional activities
- Wean from sling completely
- Begin progressive supine active elevation strengthening (anterior deltoid) with light weights (0.5-1.5 kg) at variable degrees of elevation

Late Phase III
- Resisted flexion, abduction, extension (Therabands/sport cords)
- Continue progressing IR, ER strengthening
- Progress IR stretch behind back from AAROM to AROM, as ROM allows

(Pay particular attention as to avoid stress on the anterior capsule.)

Criteria for progression to the next phase (IV):
- Tolerates AAROM/AROM/strengthening
- Achieves at least 140° AROM flexion supine
- Achieves at least 120° AROM abduction supine
- Achieves at least 60° AROM ER in plane of scapula supine
- Achieves at least 70° AROM IR in plane of scapula supine in 30° of abduction
- Able to actively elevate shoulder against gravity with good mechanics to at least 120°

Note: If above ROM are not met, then patient is ready to progress when the patient's ROM is consistent with outcomes for patients with the given underlying pathology.

Phase IV: Advanced Strengthening Phase

(Not to begin before 12 weeks to allow for appropriate soft tissue healing and to ensure adequate ROM, and initial strength.)

Goals:
- Maintain nonpainful AROM
- Enhance functional use of upper extremity

- Improve muscular strength, power, and endurance
- Gradual return to more advanced functional activities
- Progress weight-bearing exercises as appropriate

Precautions:
- Avoid exercise and functional activities that put stress on the anterior capsule and surrounding structures (eg, no combined ER and abduction above 80° of abduction)
- Ensure gradual progression of strengthening

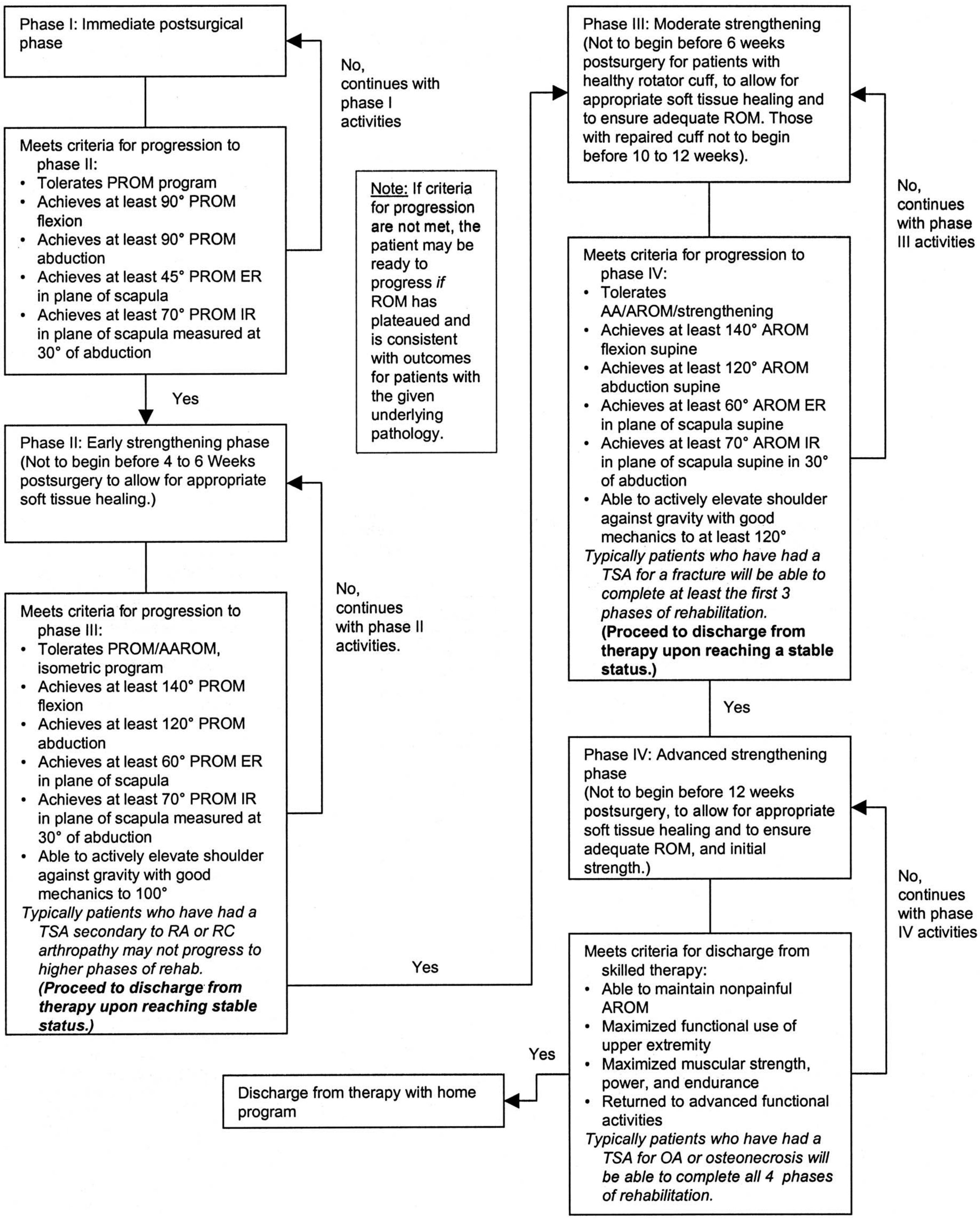
Early Phase IV
- Typically patient is on a home exercise program by this point to be performed 3 to 4 times per week
- Gradually progress strengthening program
- Gradual return to moderately challenging functional activities

Late Phase IV (Typically 4 to 6 Months Postoperative)
- Return to recreational hobbies, gardening, sports, golf, doubles tennis

Criteria for discharge from skilled therapy:
- Patient able to maintain nonpainful AROM
- Maximized functional use of upper extremity
- Maximized muscular strength, power, and endurance
- Patient has returned to advanced functional activities

APPENDIX 2

Treatment Algorithm for Progressing the Rehabilitation Program for a Patient That Has Had a Total Shoulder Arthroplasty



Abbreviations: AROM, active range of motion; ER, external rotation; IR, internal rotation; OA, osteoarthritis; PROM, passive range of motion; RA, rheumatoid arthritis; RC, rotator cuff; TSA, total shoulder arthroplasty.