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CASE REPORT

Management of a Patient With an Isolated Greater Tuberosity Fracture and Rotator Cuff Tear

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Study Design: Case report.
Background: Patients with hyperflexion/hyperabduction injury to the glenohumeral joint are at risk for isolated greater tuberosity fractures, which are often undiagnosed or misdiagnosed. In this case report, we describe the clinical decision-making process that led to the diagnosis of an isolated greater tuberosity fracture and subsequent rotator cuff tear.
Case Description: The patient was a 45-year-old male who sustained a shoulder injury as the result of a fall while skiing. After the initiation of physical therapy, he was diagnosed with an isolated greater tuberosity fracture. Little is known regarding the optimal management and overall prognosis of this type of fracture. Conservative nonoperative management and postoperative physical therapy management are discussed.
Outcomes: With conservative nonoperative management, the patient was unable to regain high-level functional shoulder use. Suspicion of continued pathology of the greater tuberosity dictated further diagnostic imaging, which led to surgical intervention. Upon completion of postoperative rehabilitation, he was able to resume full recreational activities.
Discussion: It is recommended that sound clinical decision-making dictate the management and ongoing evaluation of traumatic shoulder injuries, especially when managing a patient with an injury for which optimal treatment and prognosis is not well established. *J Orthop Sports Phys Ther 2005;35:521-530.*

Key Words: *diagnostic imaging, physical therapy, shoulder rehabilitation*

Proximal humeral fractures are quite common and the type of fracture greatly dictates the appropriate plan of care. The classification of proximal humeral fractures has been established and accepted for over 30 years. Yet, there are few reports describing the management of isolated nondisplaced greater tuberosity fractures of the humerus, which would be classified as a type I fracture using Neer's classification system.[35] Most of the recent published work on proximal humeral fractures deals with the management of 3- and 4-part fractures.[3,6,10,22,33,40,42] There are typically 2 mechanisms of injury for a greater tuberosity fracture: impaction or avulsion injury.[43,44] The impaction injury is usually the result of a fall with forced hyperflexion or hyperabduction of the shoulder. In comparison, an avulsion injury occurs in association with glenohumeral dislocation and has been found to occur in 15% to 30% of dislocations.[43,44]

Nonoperative treatment for a nondisplaced greater tuberosity fracture has been reported to include passive range of motion (PROM) starting at 1 week postinjury, active range of motion (AROM) starting at 6 weeks postinjury, followed by gradually progressed strengthening once full PROM is reached.[19] There is little evidence to support this progression timeline.

Patients with greater tuberosity fractures displaced more than 5 mm, who are managed nonoperatively, typically have less favorable outcomes than patients who are managed with a surgical repair.[31] Hence, surgical open reduction internal fixation is the treatment option of choice for displaced fractures, unless the bony fragments are small enough that their excision could be done in a manner similar to a routine rotator cuff repair. There are no published clinical series to date on either open reduction internal

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fixation and/or the excision of bony fragments.

The closest type of fracture to a greater tuberosity fracture that is described in the literature is an isolated lesser tuberosity fracture. These types of fractures are also very rare and usually occur in association with posterior shoulder dislocation or in conjunction with a comminuted proximal humeral fracture.[15] According to Ogawa et al[38] in 1997, there were only 60 published cases of isolated lesser tuberosity fractures. They reported on 10 lesser tuberosity fractures of their own and the previously reported 60 cases. These cases consisted of 52 acute cases and 18 chronic cases. The prevalence of chronic cases illustrates the fact that lesser tuberosity fractures often are misdiagnosed or completely missed at the time of injury. This is also likely true with greater tuberosity fractures. In addition, it is important when diagnosing either greater or lesser tuberosity fractures to distinguish the fracture from a rupture of the corresponding musculature.[17] Both rotator cuff tears and fractures can produce similar complaints of pain and weakness in abduction,[41,51] making it difficult to distinguish these injuries based on history and physical examination alone. Ogawa et al[39] reported in 2003 that isolated greater tuberosity fractures continue to be easily overlooked. They found that 59% (58/99) of patients with shoulder pathology seen in their clinic for second opinions had been misdiagnosed by outside facilities and did have a greater tuberosity fracture.

The purpose of this case report is to demonstrate the need for sound physical therapy clinical decision making in collaboration with the referring physician when treating a patient with an injury for which management and prognosis is not definitively established.

CASE DESCRIPTION

The patient was a 45-year-old, right-hand–dominant male who fell on his right shoulder while downhill skiing with his family (February 16, 2003), with a resultant hyperflexion injury. Initially he had some diffuse anterior shoulder pain. Over the course of a few days his pain got much worse and he noted that he was unable to raise his arm over his head. He was referred to physical therapy 16 days postinjury by an orthopedic surgeon with a diagnosis of a "right shoulder/cuff contusion" for evaluation and treatment of his shoulder. At the time of his physical therapy examination (March 3, 2003), the radiographs of his shoulder (A-P, lateral, and y-view of scapula) done 1 day postinjury had been reviewed by a radiologist and the orthopedic surgeon and were determined to be negative (Figures 1 and 2). His only treatment intervention prior to this point was a course of nonsteroidal anti-inflammatory medication (Celebrex; Pfizer, New York, NY) shortly after his injury.

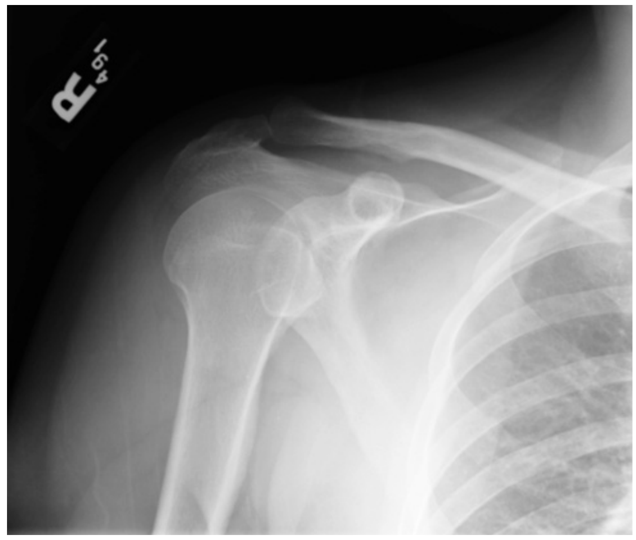

FIGURE 1. Initial radiograph, anterior-posterior view. No fracture identified.

FIGURE 2. Initial radiograph, y-view of the scapula. No fracture identified.

The patient reported no previous trauma or major injury to his shoulder, but reported some history of inconsistent bilateral shoulder pain (right worse than left) after playing tennis. This pain usually subsided after a day or so of rest. Prior to this injury, he regularly played tennis 2 days per week.

The patient's occupational role as a radiologist was partly clinical, academic, and administrative. He was able to continue working in a full capacity. The patient had difficulty reaching for objects above shoulder height, donning/doffing his shirt and coat, and was not able to actively play with his children if the activity required right upper extremity use. He was unable to play tennis. The patient's major complaint at the time of his physical therapy evaluation was intermittent achy pain: 5 on a 0-to-10 verbal analog pain-rating scale (0 representing no pain and 10 representing worst pain experienced). This pain was located anteriorly near the bicipital groove and occurred with active overhead motions. He reported a slight ache at rest. His goal was to return to all preinjury activities, including tennis.

Initial Physical Therapy Examination

This patient presented with mild anterior shoulder swelling appreciable to palpation and mild tenderness of the supraspinatus tendon at its insertion onto the greater tuberosity of the humerus. No tenderness was noted upon palpation of the rest of the shoulder girdle. Visual observation of standing posture indicated a mild forward head, protracted shoulders, and normal lumbar spine lordosis. Light touch, assessed to rule out the possibility of a peripheral nerve injury, was intact for bilateral shoulder girdles and upper extremities.

All range of motion (ROM) measurements throughout the course of his therapy were taken in the same method by the treating physical therapist (Table 1). To determine whether subacromial structures were injured and potentially inflamed, both the Hawkins[23] and Neer Impingement[36] tests were conducted and found to be positive. Due to the traumatic nature of his injury, the sulcus,[16] anterior apprehension,[27] and clunk[27] tests were performed to assess glenohumeral joint instability. Based on the 3 tests being negative, the likelihood of this patient having shoulder instability was thought to be fairly small. To screen for a possible acromioclavicular (AC) joint injury both palpation of the joint as well as an AC sheer test[9] were completed and were negative.

Because his PROM was limited, glenohumeral joint play[24,28] was assessed to determine accessory joint movement and end feel. Posterior, anterior, lateral, and caudal glides were found to be normal in both quantity of motion and end feel. Muscle performance was assessed by manual muscle testing[25]; anterior, middle, posterior deltoid, and subscapularis were all 5/5. The supraspinatus was determined to be intact by a negative empty can test,[27] but painful with resistance during a supraspinatus test[27] (6/10 pain on a verbal analog scale). Supraspinatus manual muscle testing was deferred at this time secondary to pain with the supraspinatus test. Strength of the infraspinatus was 4–/5 by manual muscle testing and moderately painful (4/10 on a verbal analog scale). Strength for other right upper extremity muscles was 5/5. These findings suggested an injury to the rotator cuff.

The presence of a painful resisted isometric contraction of his supraspinatus and palpable tenderness at its insertion onto the greater tuberosity led to a diagnosis of traumatic impingement syndrome of his rotator cuff, primarily affecting the contractile tissue of the supraspinatus muscle tendon.[8] See Table 2 for this patient's impairments and clinical goals.

It was postulated that this patient should progress well with a treatment program that focused on reducing rotator cuff inflammation, regaining rotator cuff strength, and restoring normal shoulder function. The majority of patients with subacromial impingement can be successfully managed with conservative treatment.[1] Recent studies have suggested that manual physical therapy techniques applied by physical therapists, combined with supervised exercise, are better than exercise alone for increasing strength, decreasing pain, and improving function in patients with shoulder impingement syndrome.[2,7] Additionally, a recent Cochrane review of all interventions for shoulder disorders determined that exercise was very effective in terms of short-term recovery in rotator cuff disease and had longer-term benefit with respect to function, as compared to ultrasound and laser therapy.[20] Morrison et al[34] in 1997 retrospectively looked at 616 patients who had subacromial impingement syndrome managed with anti-

TABLE 1. Right shoulder active and passive range of motion (AROM, PROM). Left shoulder AROM and PROM was 175° for flexion and abduction and 90° for internal and external rotation measured at 60° of abduction. (All measurements in degrees.)

	Postinjury			Postsurgery		
	2 wk	7 wk	13 wk	1 d	6 wk	14 wk
Flexion	130*, 170†	170, 170	175, 175	n/a, 45†	140, 174†	175, 175
Abduction	100*, 140†	160, 170	175, 175	n/a, 45†	100, 125†	175, 175
Internal rotation	80, 80‡	80, 80‡	90, 90‡	n/a, 80†§	80, 80†§	90, 90‡
External rotation	80*, 80†‡	90, 90‡	90, 90‡	n/a, 0†§	70, 80†§	90, 90‡

Abbreviations: n/a, not applicable.
*Pain.
†Pain and empty end feel.
‡Measured at 60° of shoulder abduction.
§Measured at 30° of shoulder abduction.

TABLE 2. Impairments and goals.

Initial Impairments/ Functional Limitations	Initial Goals (March 3, 2003) to Achieve in 4-6 wk	Updated Goals (March 12, 2003) to Achieve in 16 wk
	Independent with home exercise program	Independent with home exercise program
Impaired AROM/PROM	Full AROM all planes right shoulder	Full AROM all planes right shoulder
Weakness of rotator cuff due to pain inhibition	All rotator cuff musculature 5/5 by MMT	All rotator cuff musculature 5/5 by MMT
Decreased functional activity (ADL)	Able to raise right upper extremity overhead fully for all household ADL up to 10 times per h for 4 consecutive h without pain or difficulty	Able to raise right upper extremity overhead fully for all household ADL up to 10 times per h for 2 consecutive h without pain or difficulty
Decreased functional activity, recreational	Able to return to modified tennis game (no overhead serves) 2 times per wk without pain or difficulty	Able to return to modified tennis game (no overhead serves) 2 times per wk without pain or difficulty

Abbreviations: ADL, activities of daily living; AROM, active range of motion; MMT, manual muscle test; PROM, passive range of motion.

inflammatory medication and a specific supervised physical therapy routine focusing on rotator cuff strengthening. The average follow-up time was 27 months and they reported that 18% of the patients had a successful result, 67% had a satisfactory result, and 28% had no improvement and went on to have a subacromial decompression. It was also found that patients under the age of 20, and those 40 to 60 years of age, did the best with conservative management. Based on the literature and current presentation, it was believed that this patient would do well with conservative physical therapy management.

Initial Intervention

This patient's initial plan of care included ultrasound to the supraspinatus tendon, transverse friction massage, manual therapy techniques of glenohumeral joint mobilization for pain relief, a home exercise program focusing on active assisted ROM (AAROM), and ice.

Therapeutic ultrasound (0.9 W/cm^2 for 5 minutes continuous) was initially used over the insertion of the supraspinatus for the physiologic effects of promoting circulation, increasing membrane permeability, cavitation, and promotion of tendon extensibility.[32] In trying to promote circulation to the supraspinatus and knowing that there is a hypovascular zone of the supraspinatus (about 1.5 cm from the greater tuberosity),[12] the use of ultrasound was selected. However, there is very little literature supporting the efficacy of ultrasound for the treatment of either bursitis or tendonitis. Yet it is the authors' opinion that empirical patient reports that they feel better and are more flexible after a course of ultrasound treatments has maintained the enthusiasm for this modality among physical therapists.

The hypothesized role of transverse friction massage (TFM) in the treatment of tendonitis/tendinosis is primarily based on Cyriax's[8] soft tissue work. TFM is believed to assist in the reduction of abnormal fibrous adhesions allowing scar tissue to be more mobile in subacute and chronic inflammatory conditions by realigning soft tissue fibers. The effectiveness of TFM is based in theory on the changes in mechanical properties that occur with hyperemia. Most outcome reports on TFM are based on empirical data and there is no literature reporting outcomes of TFM in patients with any shoulder-related conditions. Based on the knowledge of hypovascularity of the rotator cuff and potential for improved blood flow with the use of TFM, one might speculate that TFM could be beneficial, particularly during the remodeling phase of healing. Furthermore, it is conceivable that the mechanical effects of TFM might assist in proper alignment of type I collagen fibers.

Ice helps to control pain, decrease swelling and muscle spasm, suppress inflammation, and decrease metabolism.[32] The analgesic effects occur after tissue is cooled to between 10°C (50°F) and 16°C (60°F),[37] while the depth of cooling is unknown. Speer et al[47] reported decreased postoperative pain over the first 24 hours, with a better potential for sleep and less of a need for pain medication in patients who used ice postoperatively.

This patient was seen 2 times per week for the first 9 days of therapy. His initial physical therapy program focused on the promotion of healing with the use of ultrasound and TFM, reduction of inflammation with ice and maximizing his ROM with an AAROM exercise program. Sets of 10 repetitions of grade II lateral glenohumeral joint traction (short axis distraction) and[50] caudal humeral glide (long axis distraction)[50] were done to assist in general pain relief and reduction of glenohumeral hypomobility. The patient performed AAROM with a cane for supine shoulder flexion, abduction, and external rotation at 30° of shoulder abduction, and standing extension and internal rotation behind his back. He avoided pain with his ROM exercises and completed 10 slowly performed stretches for 20 seconds for each exercise 2 times per day, followed by 20 minutes of ice to his shoulder.

Updated Examination Findings

Because the patient demonstrated no significant changes in pain relief or function within the first 9 days of therapy, an MRI was performed (March 12, 2003), which revealed a nondisplaced complete greater tuberosity fracture with associated subacromial bursitis (Figure 3). The greater tuberosity fragment measured approximately 0.7 × 0.3 cm. Rotator cuff tissues appeared normal. Consequently, his diagnosis, prognosis, and treatment plan were modified.

Updated Intervention

To assist with the modification of the patient's treatment plan and prognosis, a review of the literature was performed. This patient was seen in early 2003, before publication of the literature review on greater tuberosity fractures by Green and Izzi.[19] Because there was little literature on greater tuberosity fractures, the treating therapist also reviewed the literature on lesser tuberosity fractures. It was felt that having a sound understanding of the management of a similar fracture type would assist in the clinical decision-making process. It has been reported that removal of lesser tuberosity fracture fragments leads to poor outcomes because it does not allow for recovery of the muscular strength of the subscapularis muscle.[26] It is reasonable to conclude that this experience would apply to greater tuberosity fractures and the supraspinatus/infraspinatus muscles as well. Ogawa et al[38] reported that 3 out of 5 of 52 lesser-tuberosity cases that were treated acutely with open reduction internal fixation had excellent outcomes; yet there are no randomized controlled studies to determine if patients would do just as well without surgical intervention. In the management of patients with chronic greater tuberosity fractures it has been reported that the first choice of intervention is conservative treatment, focusing on strengthening the rotator cuff musculature while protecting the fracture site.[38]

Given the lack of literature dealing with conservative management of greater tuberosity fractures and the diagnosis of a nondisplaced greater tuberosity fracture, the treating physical therapist, in collaboration with the orthopedic surgeon, agreed to manage this patient's case similarly to that of a patient with a chronic rotator cuff tear/impingement. See the revised rehabilitation goals in Table 2. Treatment consisted of a gradual progression to ensure protection of the fracture site, while restoring shoulder function. In anticipation of restoring normal function of the shoulder the treatment program focused on appropriate rest and maintaining ROM, with eventual regaining of rotator cuff strength. Because the MRI established the absence of a rotator cuff tear, it was felt that this patient's outcome would most likely be better than that of a patient with a rotator cuff tear, as bone tissue typically heals much better than the avascularized area of the rotator cuff. This prognosis was made assuming that the fracture site healed without displacement.

This patient was then seen 1 time per week from week 4 postinjury through week 7 postinjury. Ultrasound and TFM were discontinued based on his new status. His revised physical therapy program still focused on maximizing his ROM with an AAROM exercise program. His AAROM program was the same as before his MRI; however, he was instructed to only complete these exercises 1 time per day followed by 20 minutes of ice to his shoulder. Isometric exercises were begun during week 5 and performed at 20° of shoulder abduction (to reduce the strain on his rotator cuff) for the biceps, triceps, anterior deltoid, middle deltoid, posterior deltoid, and internal rotators of the shoulder. He did not start any isometric exercises for his external rotators and abductors because any attempt at an isometric contraction of these muscle groups resulted in both immediate and residual pain. This was believed to be because he was placing too much tension through the fracture site with each contraction.

At 7 weeks postinjury his AROM/PROM was much improved (Table 1). His physical therapy visits increased to 2 to 3 times per week at week 7 of therapy

FIGURE 3. Initial coronal section MRI 4 weeks postinjury. The fracture is indicated with arrows. There is no evidence of either a rotator cuff tear or bony avulsion.

to gradually progress his strengthening program. Progressive resistance exercises of every muscle except his shoulder external rotators and abductors were begun at this point because he was pain free with daily activities, his PROM was nearly normal, and he was able to complete near maximal isometric contractions for all his shoulder musculature except his supraspinatus/infraspinatus. He began isotonic internal rotation at 20° of abduction with resistance band (Strechwell, Inc, Newtown, PA), bicep curls and triceps extensions with 0.9-kg weights, and isometric scapular retractions. He was started on shoulder external rotation and abduction isometric exercises at about 12 weeks postinjury because he had no pain with a resisted isometric contraction of either muscle. At 13 weeks postinjury his AROM/PROM was normal (Table 1). At this time he progressed his abduction isometric exercises to isotonic abduction with his arm in external rotation in the plane of the scapula (full can supraspinatus raises) and his external rotator isometric exercises were progressed to performing isotonic shoulder external rotation exercises in sidelying at 20° of shoulder abduction. He began all his strengthening exercises with 10 repetitions of AROM with no weight and progressed based on DeLorme's principles of progressive resistance exercise.[11] It was noticed that with his abduction exercises in the plane of his scapula he was unable to avoid hiking his shoulder, even with verbal cueing and visual feedback from a mirror. His shoulder hiking was believed to be secondary to inappropriate recruitment of his supraspinatus muscle due to the prolonged period of rest after his injury. An auditory and visual biofeedback unit (Prometheus Group, Dover, NH) was used for 3 weeks (weeks 13 through 15). Biofeedback electrodes were placed on both his anterior and middle deltoid while he performed 2 to 3 sets of 10 repetitions of shoulder flexion and abduction in the plane of the scapula to assist him in reducing recruitment of the deltoid with these motions. Over the course of 3 weeks he was able to completely eliminate his tendency to excessively hike his shoulder when he raised his arm over his head. He then progressed through his strengthening program so that he was completing 3 sets of 15 repetitions using 2.2 kg for bicep curls, 0.9 kg for shoulder external rotation sidelying at 20° of abduction, resistance band equivalent to 2.7 kg for internal rotation at 20° of shoulder abduction, and 0.9 kg with each of the following exercises: abduction in the plane of the scapula with his upper extremity in external rotation (full can supraspinatus raise), prone shoulder extension at 20° of abduction, and prone horizontal abduction at both 90° and 120° of abduction at 17 weeks postinjury.

The patient's desire to return to high-level recreational tennis lead the therapist and patient to work toward overhead shoulder strengthening and sport-specific activities at 4½ half months postinjury. The program consisted of a gradually progressed regime of 1 set of 10, progressed to 4 sets of 20 over the course of 3 weeks of each of the following activities: underhand tennis ball throw, overhead tennis ball throw, forehand and backhand tennis strokes with and without racket in hand, and overhead serve motion with and without racket in hand. This program revealed a significant deficit in shoulder external rotation strength when his upper extremity was above 90° of shoulder abduction. With continued strengthening focusing on overhead activities, no gains were achieved. At 20 weeks postinjury, his strength gains had plateaued: anterior, middle, posterior deltoid were all 5/5, subscapularis was 5/5, supraspinatus was 4–/5 (mildly inhibited by pain), teres minor/infraspinatus was 3–/5 (inhibited by pain when tested at 90° of shoulder abduction); yet his external rotation resisted isometric test at 0° of shoulder abduction was pain free and strong. Any attempt at overhead activity that required maximal external rotation ROM at or above 90° of abduction was painful. Otherwise he was pain free with all activities.

Because he was still having difficulty producing a strong pain-free contraction of his supraspinatus muscle, his external rotator strength had declined despite strengthening exercises, and he had pain with overhead activities, the therapist and surgeon felt that there was either a rotator cuff tear where it attached to the greater tuberosity or the original fracture was displaced. A repeat MRI (July 22, 2003) was completed that showed high T2 signal intensity in the

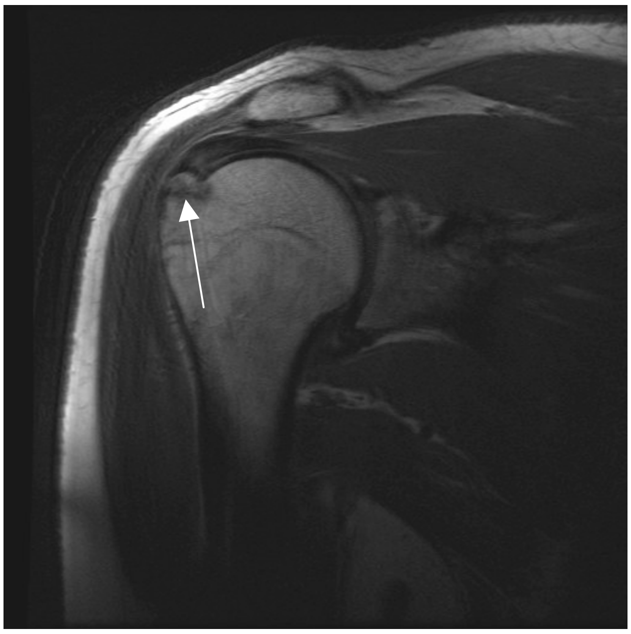

FIGURE 4. Coronal section MRI 5 months postinjury. A full thickness supraspinatus tear, a bony avulsion of the greater tuberosity, and resolving greater tuberosity edema are present. The bony avulsion is indicated with an arrow.

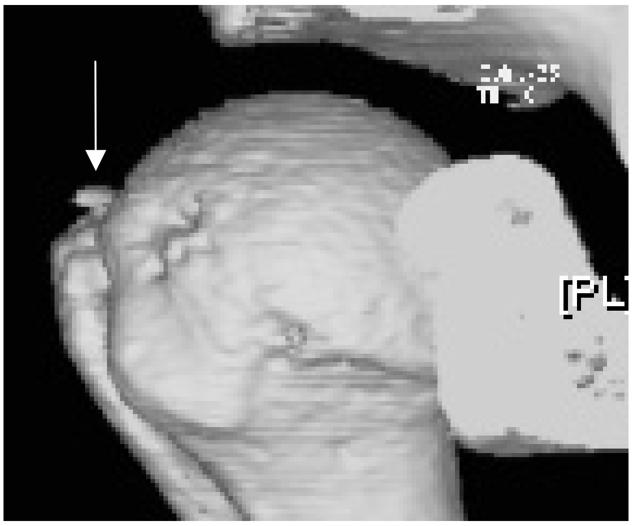

FIGURE 5. 3-D reconstructed CT scan 5 months postinjury. The bony avulsion is indicated with an arrow.

distal supraspinatus tendon (most suggestive of a full-thickness tear), a bony avulsion of the greater tuberosity, and resolving greater tuberosity edema. The original fracture line was also seen (Figure 4). The question remained as to whether this bony avulsion was a new fracture or one that was missed on the original MRI. A 3-D reconstructed computed tomography (CT) (July 24, 2003) scan was performed, which supported the most recent MRI findings (Figure 5).

Surgical Intervention

The patient's desire to return to high-level recreational tennis led him to elect to undergo surgery 5½ months after the initial injury (July 29, 2003). Arthroscopic assessment of his shoulder indicated dense hemorrhagic bursal adhesions in the subacromial space, significant inflammation of the glenohumeral joint, mild labral fraying, mild rotator interval synovitis, a supraspinatus tear, and no bony avulsion fragment. His surgical procedure consisted of arthroscopic subacromial bursectomy and an arthroscopic rotator cuff repair.

Postsurgical Physical Therapy Examination

On postoperative day 1 his pain was a 7 on a 0-to-10 verbal analog scale and his surgical right upper extremity was supported in an UltraSling II (dj Orthopedics, Inc, Vista, CA). He was referred to physical therapy to begin pendulums and PROM exercises. Upon examination his shoulder PROM was limited due to pain (Table 1). He had no neurological impairments and his cervical spine, elbow, and wrist screen were normal. Table 3 provides the details of his postoperative impairments and rehabilitation goals.

Postsurgical Intervention

The patient began pendulums and PROM exercises on postoperative day 1. During the first 5 postoperative weeks, PROM (flexion, abduction, extension, and internal and external rotation at multiple angles of abduction) in available pain-free ROM was either conducted by a physical therapist or the patient's wife, who was instructed how to perform PROM properly. Patient-performed ROM exercises were discouraged because EMG studies have shown that the rotator cuff is active with self-assisted ROM.[13] He started an AAROM program during his fifth postoperative week. These exercises were introduced to increase muscle activity and assist in restoring normal patterns of muscle contraction. His exercises for AAROM were performed with a cane for supine flexion, abduction, and external rotation at 30° of shoulder abduction, and standing extension and internal rotation behind his back. He avoided pain and completed 10 repetitions for each exercise 2 times per day, followed by 20 minutes of ice to his shoulder. By the sixth postoperative week he had no complaints of pain except at end of available ROM. He began AROM exercises during this sixth postoperative week, performing supine flexion, abduction, and internal rotation, and sidelying external rotation, and standing and prone extension twice a day each for 10 repetitions, followed by 20 minutes of ice. He was seen in the clinic 1 to 2 times per week, with his in-clinic therapy from the sixth to eighth postoperative week consisting of gradually progressed glenohumeral joint mobilizations and contract-relax techniques[48] to assist in maximizing his external rotation and flexion ROM. Sets of 10 repetitions of grades II and III lateral glenohumeral joint traction (short-axis distraction)[50] and caudal humeral glide (long-axis distraction)[50] were done to assist in general pain relief and reduction of glenohumeral hypomobility. Contract-relax techniques for external rotation and flexion were used in repetitions of 5, with 2 sets to assist with reducing antagonist glenohumeral muscle tightness of his internal rotators and extensors, respectively. His ROM progressed as expected (Table 1).

A scapular muscular and rotator cuff isometric program was initiated during his sixth postoperative week. This consisted of standing and supine scapular retractions, internal rotation, external rotation, flexion, abduction, and extension isometrics at 0° to 20° of abduction. Each exercise was performed twice a day with 10 repetitions. He began isotonic rotator cuff strengthening at 8 weeks postoperatively. Internal rotation was started with resistance band at 0° of abduction, external rotation and abduction were initiated in sidelying with a 0.45-kg weight. Shoulder flexion with 0.45 kg was performed in supine up to 180°. Once the patient was able to perform 3 sets of

TABLE 3. Postoperative impairments and goals.

Impairments/Functional Limitations	Short-Term Goals	Long-Term Goals to Achieve in 4-6 mo
	Independent with home exercise program to restore shoulder ROM (to achieve in 3 visits)	Independent with home exercise program to maintain good rotator cuff/shoulder strength
Impaired AROM/PROM	Full PROM all planes right shoulder (to achieve in 4 wk); full AROM all planes right shoulder (to achieve in 8 wk)	
Weakness of rotator cuff due to postoperative status	Strong and pain-free resisted isometric of all rotator muscles in neutral position (to achieve in 10-12 wk)	All rotator cuff musculature 5/5 by MMT
Decreased functional activity (ADL)	Able to perform all activities of daily living with upper extremity below 90° of elevation without difficulty (to achieve in 12 wk)	Able to raise right upper extremity overhead fully for all household ADL up to 10 times per h for 4 consecutive h without pain or difficulty
Decreased functional activity (recreational)		Able to return to modified tennis game (no overhead serves) 2 times per wk without pain or difficulty
Pain	Postoperative pain resolved and no pain with full AROM of shoulder all planes (to achieve in 8 wk)	

Abbreviations: ADL, activities of daily living; AROM, active range of motion; MMT, manual muscle test; PROM, passive range of motion; ROM, range of motion.

10 repetitions of the exercise with 1.36 kg, the exercise was reduced back to 0.45 kg and performed with the patient's trunk inclined 30° from the horizontal. The same progression was followed at 30°, 45°, and 60° until the patient was able to complete full flexion in standing with 0.45 kg. Full can supraspinatus raises were then introduced, starting with no weight and progressing until the patient could perform 3 sets of 10 to 15 repetitions with 1.81 kg. Both empty (internal rotation) and full can shoulder elevation in the plane of the scapula have been shown to be effective exercises for supraspinatus strengthening.[49] However, MRI studies have shown that the subacromial space is reduced with the combination of abduction and internal rotation.[18] Because there is greater risk of impingement with shoulder elevation with internal rotation, the authors prefer having patients postoperatively start with sidelying abduction to 45° to initially recruit the supraspinatus, followed by open-can supraspinatus exercises. The patient progressed through his strengthening program so that he was completing 3 sets of 15 repetitions using 2.27 kg for bicep curls, 1.36 kg for external rotation sidelying at 20° of abduction, resistance band equivalent to 4.54 kg for internal rotation at 20° of abduction, and 1.81 kg with abduction in the plane of the scapula with his upper extremity in external rotation (full can supraspinatus raise), and 1.36 kg with each of the following exercises: prone shoulder extension at 20° of abduction, prone horizontal abduction at both 90°, and 120° of abduction at 17 weeks postinjury.

A sport-specific training program, as outlined earlier, was initiated on his fourteenth postoperative week in conjunction with his progressive rotator cuff strengthening program.

Outcomes

By 14 weeks postsurgery the patient demonstrated normal ROM and strength (5/5) of his rotator cuff musculature, rhomboids, middle trapezius, lower trapezius, latissimus dorsi, and serratus anterior. Rehabilitation was continued with a home exercise program 3 times per week. He returned for reassessment 21 weeks postoperatively. His ROM was normal, he was relatively pain free with overhead movements (1/10 on a verbal analog scale), and he had started hitting some tennis balls.

Hand-held dynamometry was used to provide a more objective strength assessment of his rotator cuff.[4,5,14,21,29,30,45] The shoulder external/internal rotation isometric strength ratios at 90° of abduction with a modified Smidt[46] protocol using a Microfet 2 hand-held dynamometer (Hogan Health Industries, Draper, UT) were calculated from the average of 3 trials. Evaluation of his left shoulder (noninvolved) demonstrated that his external rotators were 75% of the strength of his internal rotators, while on his involved right shoulder (dominant), his external rotators were only 56% of the strength of his internal rotators. Because his external rotation strength was proportionately weaker on the right, his home exercise program was modified and updated to emphasize his external rotators. He was instructed to continue with his external rotation resistive band exercises at multiple angles of abduction (10°, 30°, and 60°), his sidelying external rotation ROM (at 0° and 20° of abduction) with 1.81 kg 2 to 3 times per week, but to now add a third set of each external rotation exercise, while cutting his internal rotation strengthening program down to just 1 set of resistive band exercise at 60° of abduction 3 times per week. He was formally discharged from physical therapy at that time (December 12, 2003); however, since then he has contacted the primary author on multiple occasions and stated that he is back to playing tennis on a regular basis without difficulty.

DISCUSSION

As it was the case for this patient, radiographs may not show a greater tuberosity fracture if not displaced.[41] The early use of MRI allowed for an accurate diagnosis of the fracture, which assisted the therapist and surgeon to structure a conservative treatment plan that would allow for adequate healing. The only nonimaging assessment that has been reported as clinically effective in identifying an isolated nondisplaced greater tuberosity fracture is the presence of tenderness on the lateral wall of the greater tuberosity.[39] One could argue that greater tuberosity tenderness could also be the result of inflammation of the cuff at its attachment, either from overuse or as the result of a tear. The presence of adhesive capsulitis, an anterior labral tear, glenohumeral arthritis, as well as the presence of a tumor may also cause tenderness in this area.

Conservative management for this patient, focusing on rest, maintenance of ROM, symptom-driven progression of rotator cuff strengthening, and a gradual restoration of shoulder function, resulted in a good initial outcome. The patient maintained full ROM, had no pain at rest, and was able to complete all of his activities of daily living without difficulty. However, the desire to return to high-level recreational tennis led the therapist and patient to work on overhead shoulder and sport-specific activities. This program revealed a significant deficit in external rotation strength above 90° of abduction. At that point the question whether there was continued pathology was raised. Follow-up imaging—both MRI and 3-D reconstructive CT scan—demonstrated the presence of a greater tuberosity avulsion and a small cuff tear that were believed to have hindered his ability to play tennis. Hence, surgical intervention was indicated. His postoperative course was straightforward and consistent with most arthroscopic rotator cuff protocols. The overall outcome was positive because sound clinical decision making and collaboration with the referring surgeon provided for an accurate diagnosis with a timely and appropriate treatment plan.

CONCLUSION

Physical therapists need to be aware that patients with greater tuberosity fractures can present with similar symptoms as patients with rotator cuff injuries. The possibility of a greater tuberosity fracture, often not visible on radiographs, needs to be considered when the progress of a patient with a traumatic injury is not achieved in an expected time frame or if worsening of symptoms occur. In these cases it is recommended that timely diagnostic imaging be used for both initial and ongoing evaluation. This particular patient had the added complexity of having a small rotator cuff tear that subsequently developed after his initial injury.

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