Isolated Rupture of the Subscapularis Tendon

RESULTS OF OPERATIVE REPAIR

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ABSTRACT: Sixteen consecutive patients were managed operatively for repair of an isolated traumatic rupture of the subscapularis tendon in the absence of avulsion of the lesser tuberosity. All of the patients were men. The diagnosis was made for each patient on the basis of the clinical examination and was confirmed by imaging studies and operative exploration. The operative treatment consisted of mobilization of the subscapularis after exploration and protection of the axillary nerve, transosseous reinsertion of the tendon to a trough created at the lesser tuberosity, closure of the rotator interval, and protection of the shoulder for six weeks postoperatively.

The average duration of follow-up was forty-three months (range, twenty-four to eighty-four months). Thirteen patients subjectively rated the result as excellent or good. The average functional score of the shoulder, as assessed according to the system of Constant, was 82 percent of the average age and gender-matched normal value. Active flexion was normal in twelve patients, was decreased by 15 degrees or less in three, and was severely limited in one patient. The capacity of the patients to work in their original occupations had increased from an average of 59 percent of full capacity preoperatively to an average of 95 percent postoperatively (p = 0.0006). Operative treatment proved to be economically sound within the Swiss National Accident Insurance system.

The quality of the result did not depend on the capacity for work at the time of the operation, on the type of work in which the patient was engaged, on the state of the biceps, or on the duration of follow-up. Conversely, the results were less successful when there was an increased delay from the time of the injury to the time of the operative repair.

The treatment of an isolated rupture of the tendon of the subscapularis muscle has been addressed in only a few studies, each comprising a limited number of patients. The injury typically has been attributed to a complication of a traumatic anterior dislocation of the glenohumeral joint. In 1991, Gerber and Krushel described in detail the clinical, radiographic, and operative findings in a series of sixteen patients who had an isolated tear of the subscapularis tendon. Although recognition of the entity has become widespread and the use of magnetic resonance imaging has allowed the diagnosis to be made more accurately to our knowledge, the outcome of operative treatment of this condition has not been documented in the literature. The purpose of this study was to determine the results of operative repair of a complete, traumatic, isolated tear of the subscapularis tendon in sixteen consecutive patients.

Materials and Methods

Sixteen men had an operative repair of a complete, isolated rupture of the subscapularis tendon between October 1988 and October 1991. Patients who had an avulsion of the lesser tuberosity, a concomitant rupture of the supraspinatus tendon, or a postoperative avulsion of the subscapularis tendon after its release and repair during an operation on the shoulder through an anterior approach were excluded from the present study.

The average age of the patients at the time of treatment was fifty years (range, thirty-three to sixty years) (Table I). The dominant arm was involved in thirteen patients. All of the patients had sustained a definite injury that was associated with an acute onset of pain in the shoulder and was followed by functional impairment of the involved limb. All of the injuries were severe enough to result in a temporary working disability, with the loss of time from work ranging from two days to eleven months (average, two months). Six of the eleven patients who performed strenuous manual labor were on complete disability leave as a result of the injury of the shoulder. The mechanism of injury was forceful external rotation of the abducted upper extremity in nine patients. One patient had an initial traumatic anterior dislocation, and the mechanism of injury could not be defined precisely for six patients.

When they were first seen, all of the patients reported pain. Thirteen patients had pain at night, fifteen noted discomfort with activities in which the upper limb was elevated above the level of the shoulder, and thr-
### Table 1: Perioperative Data

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (Yrs)</th>
<th>Manual Labor</th>
<th>Capacity for Work [Per cent]</th>
<th>Mechanism of Trauma</th>
<th>Pain</th>
<th>Active Flex without Pain (Degrees)</th>
<th>Active Abduct without Pain (Degrees)</th>
<th>Passive Ext. Rot. with Arm at Side (Degrees)</th>
<th>Lift-Oil Test</th>
<th>Strength of Ext. Rot. with Arm at Side</th>
<th>Strength of Abduct (Supraspinatus Test)</th>
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<td>40</td>
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<td>Reduced</td>
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<td>Symm.</td>
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<td>+ 10</td>
<td>Weak</td>
<td>Symm.</td>
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<td>+ 10</td>
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<td>Positive</td>
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<td>Reduced</td>
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*One hundred per cent capacity for work means that the patient is able to perform strenuous work all day; 50 per cent means that the patient can perform either sedentary work all day or strenuous work for half of a day.*


teen noted discomfort with activities in which the limb was below the level of the shoulder. Twelve patients reported that they had weakness when they performed tasks requiring internal rotation of the shoulder, such as reaching behind the body, placing the hand in the back pocket, or placing the hand on the abdomen. None of the patients noted symptoms consistent with gleno-humeral instability, and none had had recurrent dislocation or subluxation. Before they were referred to us, two patients (Cases 9 and 15) already had had an open acromioplasty; one of them (Case 9) also had had a biceps tenodesis for dislocation of the long head of the biceps. The diagnosis of a tear of the subscapularis had not been made either preoperatively or intraoperatively in either patient.

Physical examination revealed that active forward elevation (flexion) and abduction of the shoulder were normal in all but three patients (Table 1). Passive external rotation was increased by at least 10 degrees in ten patients and was decreased in only one patient (Case 8), who had noted pain with motion. Manual testing of the supraspinatus muscle revealed slight weakness (strength, grade 4 of 5, meaning that the patient could hold the arm against manual resistance but the arm was weaker than that on the contralateral, normal side) in five patients. Five patients had a positive impingement.
Isolated rupture of the subscapularis tendon

Fig. 1A

Figs 1-A and 1-B: Photographs showing a patient (who had a complete rupture of the subscapularis tendon of the left shoulder) performing the lift-off test.

Fig. 1-A: The result of the test is normal for the right shoulder. The arm is brought into maximum internal rotation. On release of the hand, the patient is able to maintain maximum active internal rotation.

Fig. 1-B

The result of the test shows a pathological condition affecting the left shoulder. Maximum passive internal rotation cannot be maintained actively. The hand drops to the back and cannot be lifted off actively.

The strength of external rotation, which was tested with the arm in full external rotation at the side, was found to be weaker than that on the contralateral side in five patients.

A so-called lift-off test was performed by bringing the arm passively behind the body into maximum internal rotation. The result of this test is considered normal if the patient maintains maximum internal rotation after the examiner releases the patient's hand (Fig. 1-A). If passive maximum internal rotation cannot be actively maintained and the hand drops straight back and cannot be lifted off the spine without extending the elbow, the result is considered positive (Fig. 1-B). If the resistance is weak and the hand drops back more than 5 degrees but not all the way to the spine, the result is considered weak. The result of the lift-off test was positive for thirteen patients and weak for three.

During the study period, we developed a so-called belly-press test for shoulders that had decreased passive internal rotation, for which the lift-off test cannot be used. In this test, the patient presses the abdomen with the hand flat and attempts to keep the arm in maximum internal rotation. If active internal rotation is strong, the elbow does not drop backward, meaning that it remains in front of the trunk (Fig. 2-A). If the strength of the subscapularis is impaired, maximum internal rotation cannot be maintained, the patient feels weakness, and the elbow drops back behind the trunk. The patient exerts pressure on the abdomen by extending the shoulder rather than by internally rotating...
Figs. 2-A and 2-B: Photographs showing the belly-press test, which is performed when passive internal rotation is limited. The function of the subscapularis tendon is tested by having the patient exert pressure on the abdomen with the hand. If maximum internal rotation is maintained (the elbow remains in front of the trunk, and the wrist is not flexed) while pressure is exerted, the subscapularis tendon is functional.

Fig. 2-A: A normal result.

Fig. 2-B: A positive result. When the patient attempts to exert pressure on the abdomen with the hand, he feels weakness and cannot maintain maximum internal rotation against the resistance provided by the abdomen. The elbow drops backward, internal rotation is lost, and pressure is exerted by extension of the shoulder and flexion of the wrist.

it (Fig. 2-B). The belly-press test was positive for all eight patients for whom it was performed.

Anteroposterior, axillary, and scapular lateral radiographs were made for all patients, but they were not helpful in the diagnostic assessment. The clinical diagnosis was confirmed with use of ultrasonography in eight patients, arthrography in eight, computerized tomographic arthrography in six, and magnetic resonance imaging in ten. An operation was performed on the basis of clinical findings and conventional radiographs alone in only one patient. Three patients had one confirmatory diagnostic study, eight had two, and four had three. Complete avulsion and retraction of the subscapularis tendon was found at the time of operative exploration in each patient.

Operative Technique

The interval between the injury and the repair ranged from one to fifty-six months (average, fifteen months). All of the operations were performed with the patient under general anesthesia and in a beach-chair position. The deltopectoral approach was used in each patient. The coracoclavicular ligament was incised, and the subacromial bursa was excised. The five patients who had had a positive impingement test also had an anterior acromioplasty. An osteotomy of the coracoid process or a release of the conjoined tendon from the coracoid process was not performed. Subcoracoid impingement by the subscapularis was identified after the repair in one patient, and an interdigitating coracoplasty was performed. The supraspinatus and infraspinatus tendons were inspected and palpated from inside and outside of the joint. Patients who had a rupture of either tendon were excluded from the present study. The combination of a rupture of the subscapularis with a rupture of the supraspinatus is much more common than an isolated tear of the subscapularis. However, the diagnosis of a concomitant tear of the supraspinatus is usually known preoperatively, so these patients are in a separate diagnostic category. An intraoperative diagnosis of an unexpected, concomitant tear of the supraspinatus appears to be rare, and only one patient was excluded from the study because of that finding.

Intraoperatively, the long head of the biceps was found to have been tenodesed during a previous operation and was adherent to the bicipital groove in one patient. It was ruptured in another patient, was dislocated medially into the joint in two patients, and was thickened and abnormal in two patients. In the four patients in whom the long head of the biceps was dislocated, the bicipital groove was deepened and the tendon was relocated into the bicipital groove. The stump of the subscapularis tendon was identified underneath the conjoined tendon so that it could be mobilized. From the inside of the joint, the anterior capsule was divided vertically with an incision beginning immediately anterior to the biceps anchor to the inferior pole of the glenoid rim. This capsulotomy was carried out immediately adjacent to the anterior aspect of the glenoid labrum, leaving the capsule attached to the under-
surface of the retracted musculotendinous unit of the subscapularis. Adhesions between the surface of the subscapularis and the conjoined tendon were released. In order to perform this operative step, the neurovascular bundle, including the axillary artery and the infraclavicular plexus, was identified and protected. At the inferior border of the subscapularis, the axillary nerve was isolated and protected with a blunt right-angled retractor, as it is at particular risk when the subscapularis is mobilized by the release of adhesions between the capsule, the scapular neck, and the musculotendinous unit of the subscapularis. Adhesions between the anterosuperior aspect of the capsule, the superior border of the retracted subscapularis, and the region of the undersurface of the coracoid process were then released. The coracohumeral ligament was divided at its origin on the coracoid process, and the interval between the subscapularis and the supraspinatus was released to allow the mobilized subscapularis to glide freely relative to the supraspinatus. The lateral portion of the origin of the subscapularis muscle was then elevated from the subscapularis fossa with a rasp, for enough to allow the musculotendinous unit to be pulled to the lesser tuberosity. An osseous rough was created adjacent to the lesser tuberosity, and the tendon was reinserted with a transosseous technique and three or four number-3 braided non-absorbable sutures. Grasping the tendinous stump and the underlying capsule in one layer with a specific tendon-grasping technique, we did not observe any pulling of sutures through the tendon. The lateral aspect of the rotator interval was closed.

Postoperative Management and Evaluation

Postoperatively, the shoulder was protected in a sling for six weeks. During this period, external rotation to 0 degrees was allowed, then was steadily increased. In the initial six weeks, the patients were also allowed forward and lateral elevation of the upper limb to 60 degrees while maintaining the arm in slight internal rotation. They were not permitted to perform any strenuous work for three months after the operation, and no other specific exercises were prescribed.

All of the patients were examined clinically and radiographically by an independent examiner for the purpose of the present study. The patient's result was excellent, good, fair, or poor. In addition, they assessed the function of the shoulder with use of a visual-analog scale on which a completely normal shoulder was considered to be 100 per cent functional and a completely destroyed shoulder, 0 per cent. In addition, a score was established for each patient with use of the system of Constant (Table II). For the subjective portion of this score, pain in the shoulder was estimated by the patient with use of a visual-analog scale. The worst pain that they had during functional use of the shoulder, such as performing the duties of their occupation, was represented by a score of 0 to 15 points, with 15 points indicating that they had no pain and 0 points severe pain. The ability to work was also estimated by the patient, if he could do half of the work, 2 of 4 points were given. If he could do about one-fourth of the work, 1 point was given. The same concept was applied for leisure-time activities. If the patient could perform only three-fourths of the desired or former activities, the score was 3 points. Two points were given if sleep was normal, and 1 point was given if sleep was occasionally interrupted because of pain in the shoulder or if the patient was unable to sleep on the affected side. If the pain regularly interfered with sleep, the score was 0 points. Each patient assessed his capability to work with the involved limb at defined positions. For example, 10 points were given if he thought he could work with the arm above the head (Table II).

A clinical examination was carried out in a standard fashion. The objective assessment of pain-free active flexion and abduction was performed with the patient sitting. The range of flexion (in the sagittal plane) was measured as the angle between the humeral shaft and
the mid-thoracic line. Abduction was always measured, with simultaneous maximum abduction of both upper extremities, as the angle of the humeral shaft with the mid-thoracic line. Functional external rotation was measured, according to the system of Constant, by bringing the hand behind the head and then above the head. The hand was not allowed to touch the head during these movements. The amount of active internal rotation was determined by the spinous process that could be reached without pain by the head of the third metacarpal.

The strength of abduction was assessed with the patient standing and the upper limb abducted to 90 degrees in the scapular plane. The elbow was extended, and the forearm was pronated. An Isobax dynamometer (Corus SA: Bern, Switzerland) was used, and the resistance was applied at the wrist. Three measurements of five seconds’ duration (the B-mode of the device) were averaged to determine the strength of abduction. One point was attributed for each pound (0.45 kilogram) of strength measured, and the total score was recorded. In addition, the score for each patient was related to the age and gender-matched normal values, as identified by Constant', which allowed the score to be expressed as a percentage of normal. The strength in abduction, the strength in external rotation with the arm at the side, and the result of the lift-off test were reassessed. Anteroposterior, axillary, lateral, and scapular lateral radiographs also were made.

None of the patients had an intraoperative complication; specifically, there was no injury of a nerve or laceration of the axillary artery or its branches. Also, there were no infections or problems with the wound. Three patients lost at least 30 degrees of external rotation, and they had an arthroscopic capsulotomy at six, seventeen, and eighteen months. In one other patient (Case 9), who had had two previous operations, the subscapularis ruptured again and a reconstruction was performed twenty-four months after the index intervention.

Statistical analysis of the results was performed with use of an unpaired two-tailed t test for comparison of the averages of two groups of patients (for example, the patients who had had the operation within twenty months after the injury compared with those who had had the operation later). A paired two-tailed t test was used for analysis of the paired samples (for example, the preoperative and postoperative capacity of the patient to work). The dependence of continuous variables was assessed with use of simple regression analysis. The level of significance was p < 0.05.

Results

The patients had a follow-up examination at an average of forty-three months (range, twenty-four to eighty-four months) postoperatively (Table III). The overall result was considered excellent by eight patients, good by five, fair by one, and poor by two. On a visual-analog scale, the patients estimated the function of the involved shoulder to be 82 per cent (range, 20 to 100 per cent) of normal.

On examination, active flexion was symmetrical and considered to be normal in twelve patients, as none of them reported any problems with the contralateral shoulder. Active flexion was slightly diminished in three
patients and severely diminished in one patient. External rotation was symmetrical in ten patients; four patients had a loss of less than 10 degrees and two had a loss of more than 10 degrees of external rotation. The increased external rotation that had been present in ten patients preoperatively was no longer demonstrated. The result of the lift-off test (Figs. 1-A and 1-B) was normal in eleven patients, weak in two, and positive in three. The result of the belly-press test (Figs. 2-A and 2-B) was normal for all eleven patients who had a normal result on the lift-off test; it was positive (there was loss of maximum internal rotation when the patient attempted to press the abdomen with the hand) for the remaining five patients. Four patients had some remaining weakness on manual testing of the strength of abduction (the supraspinatus test), and five patients had some remaining weakness on testing of the strength of external rotation.

The capacity of each patient to work in his original occupation had increased from an average of 59 percent (range, 0 to 100 per cent) to an average of 95 percent (range, 50 to 100 per cent) (p = 0.006). The average relative Constant score was 82 per cent (range, 29 to 109 per cent) of that for an age and gender-matched control group and was identical to the average subjective value for the shoulder. The association between the subjective estimation and the Constant score was excellent (p < 0.005). The two lowest Constant scores (29 and 56 per cent) were observed in the two patients (Cases 9 and 15) who had a subjectively poor result. One (Case 9) had had a previous acromioplasty and a biceps tenodesis. The index repair had failed, and a second repair of the subscapularis also yielded an objectively and subjectively unsatisfactory result. The other patient (Case 15) also had had a previous acromioplasty. By the time of the most recent follow-up evaluation, acromioclavicular osteoarthrosis had developed. Injection of 1 per cent Xylocaine (lidocaine) into the acromioclavicular joint eliminated the pain, and a resection of the lateral aspect of the clavicle was planned.

On the radiographs, we observed mild osteoarthritic changes with osteophytes that were less than three millimeters wide at the humeral head or the glenoid, or both, in three patients, but there was no proximal or anterior migration of the humeral head.

With the numbers available, multivariate analysis revealed no significant association between the quality of the result and the degree to which the patient was able to work before the operation, the type of work in which the patient was engaged (strenuous labor compared with sedentary work), the need for a secondary arthroscopic release, or the duration of follow-up. The clinical results for the three patients (Cases 9, 12, and 15) who had had a long-standing rupture (for more than thirty-six months), however, were significantly less satisfactory (average relative Constant score, 59 per cent) than those for the thirteen patients who had had the operation within twenty months after the injury (average relative Constant score, 88 per cent) (p < 0.02).

The cost refunded to the hospital by the insurance carrier for the operative management of the sixteen patients was 59,200 Swiss francs (the exchange rate at the time of publication of this paper was one Swiss franc to $1.25), which was determined on the basis of a flat fee of 480 Swiss francs per day per patient. The disability reimbursement by the insurance carrier to the patient is 80 per cent of the salary received before the injury. For an average income of 48,000 Swiss francs, the baseline is 38,400 Swiss francs. For example, a patient who is on disability leave for 40 per cent of the year is paid 15,360 Swiss francs by the insurance carrier per year, and the disability payments continue until the patient is sixty-five years old. At the time of the operation, the cohort of patients had an average age of fifty years. Assuming that the results had not deteriorated with time, the insurance carrier would have been required to make disability payments of 5,686,400 Swiss francs if operative treatment had not been performed. This does not include any cost for treatment that would have been administered. With the results obtained in the present study, the patients were on disability leave for only 5 per cent of the year as a consequence of the treatment, so the disability payment was reduced to 1920 Swiss francs per patient per year. This suggests a total disability payment of 460,800 Swiss francs for the patients managed in this study. When the costs of operative and hospital treatment (59,200 Swiss francs) and payment for full disability for six months after the operation (291,840 Swiss francs) as well as for long-term disability (460,800 Swiss francs) are added, the total cost of treatment is 811,840 Swiss francs. It should be noted that none of the patients in the present study were being managed with physiotherapy or other modalities at the time of the most recent follow-up evaluation. Also, the total sum of the long-term disability payments was directed to only the two patients (Cases 6 and 9) who did not regain full working capacity. The fourteen other patients did not receive any long-term disability payments. Therefore, although it could not be determined precisely, the projected savings for the Swiss National Insurance Company due to operative treatment was estimated to be nearly three million Swiss francs for the sixteen patients.

Discussion

A partial or even a complete rupture of the subscapularis tendon in conjunction with a tear of the supraspinatus tendon is much more common than an isolated tear of the subscapularis tendon. In addition, an isolated incomplete tear of the subscapularis tendon is much more frequent than a complete avulsion of the tendon. The present study, however, addresses only the pure, but relatively rare, isolated complete rupture. In our experience, the prognosis for that lesion differs from that for
a combined tear of the supraspinatus and subscapularis.

Turkel et al. documented the biomechanical role of the subscapularis in providing anterior stability of the adducted and slightly abducted arm. Nevinson et al. reported recurrent anterior instability after rupture of the subscapularis incurred during anterior traumatic dislocation. None of our patients reported instability, and the indication for operative repair was invariably the persistence of moderate-to-severe pain with loss of strength of the shoulder. Despite the anterior capsulotomy, none of the patients had postoperative anterior instability.

Most authors have reported favorable results after operative treatment of a tear of the subscapularis tendon. Biundo and Bear reported on one patient who had such a repair. Collier and Wynn-Jones reported on another, and Theunissen et al. described two patients who had complete recovery of the function of the shoulder after repair of the subscapularis tendon. Nevinson et al. reported that stability and function of the shoulder were restored in eight patients who had had recurrent instability associated with a tear of the subscapularis. To our knowledge, only Hauser reported on a patient who could not be managed satisfactorily for anterior instability in association with a tear of the subscapularis. Our results confirmed the overall favorable prognosis for an isolated tear of the subscapularis. Our two patients in whom treatment failed originally had had operative management for an incorrect diagnosis, and thus the tear of the subscapularis was repaired a very long time after the injury. Our results suggest that a long delay between the injury and the repair adversely affects the ultimate outcome. Although quantitative assessment was not possible because not all patients had.

had comparable arthrography, computerized tomography, or magnetic resonance imaging studies, our observations suggest that a delay in treatment leads to less satisfactory results because of fatty degeneration and atrophy of the subscapularis muscle (Figs. 3 A and 3-B). In an effort to determine whether this hypothesis can be confirmed and whether there is a certain degree of muscular atrophy, degeneration, and retraction that is beyond successful repair, we are currently studying atrophy and fatty degeneration prospectively in patients who had a rupture of the subscapularis.

The most consistent preoperative findings in this series were increased passive external rotation, which was almost invariably associated with apprehension-like discomfort, and the inability to maintain passive maximum internal rotation actively. Excessive external rotation was corrected in all ten of the patients who had had that finding preoperatively. The lift-off test was refined by the observation that a small lag (a difference between maximum passive and maximum active internal rotation without the hand dropping all of the way to the spine) can occur and is specific for a small or incomplete tear. In addition, when a patient has very painful or limited internal rotation and is not able to reach behind the back, weakness during the belly press maneuver allows the diagnosis of a tear of the subscapularis tendon to be clinically suspected. Although these clinical tests substantially improved the accuracy of the diagnosis preoperatively, a positive or negative result at the follow-up examination did not have a direct association with the clinical outcome. Patients who had a positive result on the postoperative lift-off and belly press tests did not have increased external rotation. They had good
strength in internal rotation when it was tested with the arm in neutral or slight external rotation, but external rotation was weak when it was tested with the arm in internal rotation. We believe that these findings suggest that these patients had not had a complete re-rupture; instead the repair may have become elongated or the atrophy and degenerative changes of the muscle were beyond complete recovery, or both.

Operative treatment of isolated tears of the subscapularis tendon led to a significant gain in the capacity of the patients to work (p = 0.006). This was also true for the patients who were receiving disability payments. These results are a valuable argument in favor of the operative repair of such lesions. The disability with regard to work was decreased by 36 percent in this series, and although a financial benefit may not have been realized by the treating hospital the procedure was found to be beneficial in an overall economic assessment. Early repairs consistently led to a favorable outcome, whereas delayed procedures had a less satisfactory result. Therefore, our findings suggest that an attempt at non-operative treatment of an isolated complete rupture of the subscapularis tendon may not be justified.

References
Glenoplasty for Recurrent Posterior Shoulder Instability
An Anatomic Reappraisal

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Posterior glenoplasty, as performed for the treatment of recurrent posterior shoulder instability, was shown to thrust the humeral head forward and was able to cause symptomatic impingement of the anterior cuff between the coracoid process and the humeral head. Such subcoracoid impingement is relieved by resection of the inferolateral part of the coracoid tip and of the coracoacromial ligament.

Recurrent posterior shoulder instability is uncommon. The habitual, voluntary, and involuntary clinical forms defined by Hawkins et al. require different therapeutic considerations. Voluntary (intentional but not willful) and involuntary (unintentional) recurrent posterior subluxations can often be controlled with conservative therapy. Habitual recurrent posterior subluxations (called “voluntary” by other authors), which are associated with psychiatric problems, are considered to be a contraindication for operative treatment. Surgical reconstructions are thus reserved for voluntary or involuntary recurrent posterior shoulder instabilities in which rehabilitation failed to control pain and disability.

Kretzler and Blue and Scott have independently introduced posterior glenoplasty and recommended it for the treatment of such cases. Although excessive posterior tilt of the glenoid has never been a consistent or even necessary pathogenic factor, posterior glenoplasty has become a widely used standard procedure. Excellent and good results reported with this procedure have recently been contradicted by less satisfactory results.

This study documents the clinical occurrence of impingement of the anterior cuff between the humeral head and the coracoid process (subcoracoid impingement) after posterior glenoplasty. This article describes the rationale for inferolateral coracoplasty, used as a successful treatment of this complication in the case presented.

CASE REPORT

A posterior glenoplasty following exactly the technique of Scott was performed on the right

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FIGS. 1A–1F. Right posterior glenohumeral for recurrent posterior subluxation. (A) External and (B) internal rotation (note winging of scapula caused by restricted internal rotation). (C and D) Horizontal flexion and (E) internal rotation in abduction are markedly restricted on the right. (F) Flexion of the arm (driver’s position) causes paresthesias in the entire anterior arm.
shoulder of a 29-year-old man with a bilateral voluntary recurrent posterior shoulder subluxation. Through a correctly located, incomplete posterior glenoid neck osteotomy, the glenoid plane was tilted forward by 20°-25°. Throughout the postoperative course, the patient continued to complain about dull anterior shoulder pain and pain referred to the upper arm, the radial forearm, and the thumb. Clinical neurologic examination and EMG studies of the C5-C7 roots, the radial, and the musculocutaneous nerve were normal. On further follow-up examination (Fig. 1), the shoulder remained stable without apprehension, but horizontal flexion, and external and internal rotation were restricted especially in abduction. A computed tomographic (CT) examination of both shoulders was performed (Fig. 1). The left/right difference of the orientation of the glenoid relative to the body of the scapula was 25°, suggesting that the wedge of the osteotomy was in the range of 25°. The posterior glenoid tilt was 0° on the left side. The left glenoid was thus oriented as in normal shoulders, and as skeletal anatomy is usually similar in both shoulders of a given individual, most likely there had not been any excessive retroversion on the right glenoid before surgery. The size and orientation of the left and right coracoid were also within the formerly established limits of normal, so that no skeletal deformations were found responsible for the instability in both shoulders. At the painfully limited extremes of external (Fig. 1A) and internal rotation (Figs. 1B and 1H) of the right shoulder, there was unequivocal, bony impingement between the humeral head and the tip of the coracoid process. Under general anesthesia, forceful horizontal flexion produced a palpable click with apparent posterior subluxation of the shoulder. The bony coracohumeral impingement and the posterior subluxation caused by the coracoid (which, during forceful horizontal flexion, levered the humeral head out posteriorly), were confirmed at surgery when the inferolateral half of the coracoid was resected. The
patient reported immediate and complete relief from his local and referred pain after surgery. He regained a full range of motion within four months after the coracoplasty (Fig. 2) and has remained without pain and stable for 34 months.

On performing a posterior glenoplasty on the opposite shoulder, the following observations were made. With the patient on his side, the coracoid tip and the coracoclavicular ligament were identified through a deltoid splitting approach. The size of the
subcoracoid space was large enough to allow free gliding of the subscapularis tendon under the coracoid tip. The glenoplasty was performed through a usual posterior approach. On opening the osteotomy site, the head could be seen to abut against the coracoid. Internal rotation in adduction and abduction were markedly restricted because of impingement of the lesser tuberosity at the coracoid tip. Horizontal flexion led to impingement of the humeral head neck region against the coracoid. If horizontal flexion was continued, the head was pushed somewhat posteriorly with the coracoid serving as a fulcrum. Resection of the lateral half of the coracoid tip without resection of the coracoacromial ligament and the coracobiceps tendon restored an adequate subcoracoid clearance for all movements tested under anesthesia. After surgery, the range of motion in the shoulder was unrestricted and the patient has now remained pain-free and stable for 22 months.

It has been previously shown that changes in the scapulohumeral relation can decrease the coracohumeral distance to the extent to cause permanent coracohumeral contact. Mathematical analysis of the anatomic data suggested that a posterior glenoplasty in the range of 15°–25° performed on a shoulder with normal skeletal anatomy should invariably lead to subcoracoid impingement. The two shoulders operated on in this study seemed to confirm this hypothesis and warranted an anatomic study on cadaveric shoulders.

ANATOMIC STUDY

Five shoulders in three patients with voluntary recurrent posterior shoulder subluxations could be studied with computer tomography to establish the validity of an anatomic study to be performed on normal shoulders. The retrotilt of the glenoid fossa determined by CT was between 0°–10° in all five shoulders; none of them showed an abnormal glenoid, a deformed humeral head, or an abnormal anterior or posterior displacement on ro-
tation of the adducted arm as determined by full internal and external rotation CT pictures. The size and orientation of the coracoid process were also within the normal range.\textsuperscript{5} An anatomic study performed on normal shoulders was considered a valid model for the assessment of the changes in the coracohumeral relationship caused by posterior glenoplasty.

Thirteen glenoplasties were performed on the shoulders of seven cadavers. It was not possible to obtain any history concerning previous shoulder problems in these subjects. Dissection of the shoulders did not reveal traumatic lesions, evidence of advanced degenerative changes, inflammatory or cuff disease, or skeletal anomalies. Thus, these shoulders were considered normal. Reorientation of the glenoid with a wedge of between 15° - 25° (base of the prismatic bone graft always less than 1.5 cm) invariably led to impingement of the anterior cuff and humeral head beneath the coracoid (Fig. 3), and to some extent, beneath the coracoclavicular ligament. The coracohumeral contact areas were the lesser tuberosity and coracoid tip in internal rotation of the adducted and the abducted humerus, the region of the bicipital groove, and the coracoid tip in horizontal flexion. Coracohumeral contact markedly restricted the range of these movements. If the flexed humerus was adducted (Fig. 1C) to reproduce the position of clinical subluxation, the humeral neck abutted against the coracoid and the shoulder was pushed out posteriorly with the coracoid serving as a fulcrum as seen in the case report. In six of the tested shoulders however, this was only obtained by horizontal flexion beyond 120°.

An attempt was made to prevent subcoracoid impingement without the need of an additional anterior surgical approach. The posterior scapular neck was osteotomized medial to the base of the coracoid process. This modification allowed rotation of the coracoglenoid fragment anterolaterally despite the intact coracoclavicular ligament. The necessity to osteotomize the anterosuperior scapular neck from the back, however, led to a complete glenoid osteotomy with an unstable coracoglenoid fragment in three consecutive experiments. As this hinders the control of the correction of the glenoid tilt and renders stabilization of the glenoid fragment difficult, osteotomy medial to the coracoid base was rejected. In nine other experiments, the authors added a small deltoid splitting anterior approach centered over the coracoid and resected the lateral half of the coracoid tip together with the coracoclavicular ligament. This left the coracoclavicular ligaments, as well as the tendinous insertions of the pectoralis minor and the coracobrachialis, intact. This procedure restored an adequate subcoracoid clearance in all nine experiments.

**DISCUSSION**

Subcoracoid impingement of the rotator cuff after glenoplasty has not been recognized as an important complication of this procedure. In the original description of Scott,\textsuperscript{15} however, Patient 1 had a prolonged history of chronic pain and his shoulder adduction was limited to 0°. The detailed case report suggests that this patient suffered from subcoracoid impingement as described here. Other authors do not report a restricted range of motion in the operated shoulders.\textsuperscript{13,9,14,16} In some of these reports, however, the preoperative range of motion of the patients was not measured.\textsuperscript{13} and horizontal flexion and rotation of the abducted arm have apparently never been recorded.

The degree of the created coracohumeral conflict created by posterior glenoplasty depends on the individual anatomy before surgery, the amount of the created anterior tilt, and possibly the degree of capsular laxity (allowing posterior translation of the humeral head on contact between the subscapularis and the coracoid tip). The possible combinations of these factors may account for the different clinical expressions of this syndrome, which range from severe disability, as in this case, to its apparent absence in published cases in the literature.
Figs. 3A-3C. Anatomic cross section at the level of coracoid tip. (A) Coracohumeral clearance before glenoplasty. (B) After glenoplasty using a wedge-shaped graft with a base of 1 cm (white arrows, graft; black arrow, subcoracoid impingement area; open arrow, subcoracoid impingement causes mild posterior displacement of the humeral head). (C) After glenoplasty and coracoplasty. Black arrow shows that subcoracoid impingement is relieved although the humeral head (open arrow) is again centered in the glenoid fossa.

One of the authors has clinically examined seven additional shoulders with a posterior glenoplasty performed by different surgeons. Although not all of these patients complained spontaneously, none were completely free of anterior shoulder pain and none had normal (symmetrical) internal rotation in abduction and unlimited horizontal flexion. The pain could consistently be reproduced by horizontal flexion/internal rotation and 90° abduction/internal rotation. Thus, directed interview and specific clinical examination revealed mild to moderate signs and symptoms compatible with subcoracoid impingement in all these cases.

Significant problems with posterior glenoplasty have been reported in the detailed study of Hawkins et al.7 There were seven recurrences and five other complications in 17 operations. Four of the five complications remained largely unexplained. They included one severe osteoarthrosis with an external rotation contracture, one ulnar nerve neurapraxia that resolved after three months, one patient with stiffness lasting over 12 months, and one patient with unremitting shoulder pain. Unremitting, referred pain, stiffness, and limited internal rotation were also complaints of the patient in this study. Similar findings have been reported in subcoracoid impingement secondary to procedures other than posterior glenoid osteotomy.6 Also, a painful syndrome closely resembling ulnar nerve neurapraxia has formerly been described by
Goldthwait\(^6\) in idiopathic subcoracoid impingement. Some of the hitherto unexplained complications described in the reports of Scott\(^5\) and Hawkins \textit{et al}.\(^7\) are thought to be compatible with subcoracoid impingement.

This anatomic study was performed on normal shoulders of fresh, unselected cadavers. This study could be questioned if nonparalytic recurrent posterior shoulder instability was caused, or consistently associated with, defined anatomic abnormalities. Abnormal glenoid orientation has been considered a possible etiologic factor\(^4\) for recurrent anterior shoulder dislocation, but more recent studies have not substantiated this contention.\(^2\) English and Macnab\(^5\) have claimed that recurrent posterior shoulder instabilities are associated with increased glenoid retroversion and that posterior glenoplasty treated a cause of the subluxation. Their contention was based on supine axillary roentgenograms and referred to the spatial orientation of the glenoid relative to the axis of the condyles of the elbow, which was placed parallel to the examination table. Such glenoid retroversion measurements depend on the position of the patient on the examining table, \textit{i.e.}, shrugging the shoulders, and yield little information on the glenoid orientation in respect to the scapular body or to the coracoid process. Although abnormal skeletal anatomy may, in certain cases, be a pathogenic factor, we know as yet of no scientific evidence that skeletal abnormalities are necessary for the occurrence of posterior shoulder instability. Because computed tomographic analysis of five shoulders with recurrent posterior shoulder instability showed normal skeletal anatomy, cadaveric study on normal shoulders was considered adequate.

In this anatomic study, glenoplasty consistently produced impingement of the subscapularis between the coracoid tip and the humeral head. Furthermore, it demonstrated that the coracohumeral conflict in horizontal flexion/internal rotation can lead to levering the humerus posteriorly out of the joint. Because this occurred in the usual position of posterior subluxation, the possibility that the tip of the coracoid can play a role in the development of recurrence in some cases of posterior glenoplasty cannot be overlooked. Conversely, because the functional importance of the coracoid is still poorly understood it can not \textit{a priori} be excluded that its partial removal could jeopardize anterior stability. At this time, removal of the inferolateral part of the coracoid has had no inadvertent effects,\(^4\) at least when the insertion of the short head of the biceps, the coracobrachialis, and the pectoralis major tendons were preserved.

Based on the clinical observations and the results of the anatomic study presented, subcoracoid impingement is an important potential complication of posterior glenoplasty if performed as recommended. Its presence can intraoperatively be recognized by detecting reduced horizontal shoulder flexion and/or reduced internal rotation of the 90\(^\circ\) abducted arm. In patients with anterior shoulder and arm pain after a glenoplasty, CT analysis of the coracohumeral relationship may be warranted to confirm or exclude this complication. Inferolateral coracoplasty appeared to relieve this form of iatrogenic subcoracoid impingement. If this procedure is considered as an adjunct to posterior glenoplasty, however, it is important to be aware that the role of the coracoid process for the functional anatomy of the shoulder, especially in respect to stability, remains to be established.

REFERENCES

5. Gerber, C., Terrier, F., Zehnder, R., and Ganz, R.:


