Arthroscopic tenotomy of the long head of the biceps in the treatment of rotator cuff tears: Clinical and radiographic results of 307 cases

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The purpose of this study is to evaluate the objective, subjective, and radiographic results of arthroscopic biceps tenotomy in selected patients with rotator cuff tears. Three hundred seven arthroscopic biceps tenotomies were performed in patients with full- thickness rotator cuff tears. Patients were selected for arthroscopic tenotomy if the tear was thought to be irreparable or if the patient was older and not willing to participate in the rehabilitation required after rotator cuff repair. Patients were evaluated clinically and radiographically at a mean of 57 months' follow-up (range, 24-168 months). The mean Constant score increased from 48.4 points preoperatively to 67.6 points postoperatively ($P < .0001$). Eighty-seven percent of patients were satisfied or very satisfied with the result. The acromiohumeral interval decreased by a mean of 1.3 mm during the follow-up period and was associated with a longer duration of follow-up ($P < .0001$). Preoperatively, 38% of patients had glenohumeral arthritis; postoperatively, 67% of patients had glenohumeral arthritis. Concomitant acromioplasty was statistically associated with better subjective and objective results only in patients with an acromiohumeral distance greater than 6 mm. Fatty infiltration of the rotator cuff musculature had a negative influence on both the functional and radiographic results ($P < .0001$). Arthroscopic biceps tenotomy in the treatment of rotator cuff tears in selected patients yields good objective improvement and a high degree of patient satisfaction. Despite these improvements, arthroscopic tenotomy does not appear to alter the progressive radiographic changes that occur with long-standing rotator cuff tears. (J Shoulder Elbow Surg 2005;14:238-246.)

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Full-thickness tears of the rotator cuff tendons are common and are a frequent cause of dysfunction of the shoulder. Nonoperative management has a satisfactory outcome in 40% to 82% of cases; however, narrowing of the acromiohumeral interval occurs in nearly three fourths of patients within 5 years with nonoperative treatment of full- thickness rotator cuff tears.[4,5,23,24,35] In addition, Hamada et al[20] showed that 5 of 7 full-thickness rotator cuff tears treated nonoperatively and followed for a minimum of 8 years had progression of glenohumeral arthritis of at least 1 radiographic stage.

Arthroscopic acromioplasty has yielded good early objective and subjective results in 70% to 90% of cases of rotator cuff tears, especially in small- and medium-sized tears.[8,9,29,39] Gartsman[12] found less satisfactory outcomes in massive tears, and Zvijac et al[53] showed that the promising early results of arthroscopic acromioplasty deteriorated with longer follow-up. The results of rotator cuff repair are generally recognized to be better than those of isolated acromioplasty.[13,31,37] Although rotator cuff repair has been reported to be a highly successful procedure, the outcome for patients undergoing repair of large or massive rotator cuff tears is distinctly less satisfactory, with a retear rate of 36% to 70%.[14-16,21] In addition, attempts at repair of massive rotator cuff tears with static superior subluxation of the humeral head or massive rotator cuff tears involving the subscapularis or the teres minor may have a detrimental effect, resulting in postoperative loss of active elevation or even development of a pseudoparalytic shoulder.[16,47,52] Some authors have stated that age at the time of repair and sex do not appreciably affect the outcome, whereas others have reported poorer outcomes in individuals aged greater than 65 years and in female patients.[22,43] Finally, fatty infiltration of the rota-

tor cuff musculature has been reported to be the most important predictor of clinical results after rotator cuff repair.[16,18,19] Although muscular atrophy may be arrested or reversed after repair of supraspinatus tears, fatty infiltration is irreversible.[16,18,19,46]

Spontaneous rupture of the long head of the biceps is common during the evolution of rotator cuff tears.[33] Surgery is rarely required because this event is commonly associated with pain relief after the acute episode subsides. The very small number of published articles reporting the results of repair of a ruptured long head of the biceps tendon attests that this condition is well tolerated.[28,45,51]

After observing multiple patients with chronic rotator cuff tears obtain pain relief shortly after rupturing the long head of the biceps tendon, the senior author hypothesized that in selected cases (patients with irreparable tears and patients unwilling to participate in the required rehabilitation after rotator cuff repair), tenotomy of the long head of the biceps tendon may provide acceptable treatment. The senior author began performing arthroscopic biceps tenotomy in 1988. Early- and middle-term results with the procedure have been promising.[17,38,48] The purpose of this study is to report the results of arthroscopic biceps tenotomy in the treatment of rotator cuff tears in a consecutive series of patients with longer follow-up (2-14 years).

MATERIALS AND METHODS

Between January 1988 and December 1999, 1469 full-thickness rotator cuff tears underwent surgery by the senior author. Of these, 1079 were repaired and 390 underwent arthroscopic tenotomy of the long head of the biceps with no attempt at rotator cuff repair. In all patients, appropriate nonoperative management, including rest, rehabilitation, antiinflammatory medications, and/or corticosteroid injections, had previously failed. All patients had subjectively unacceptable pain for a minimum of 3 months in duration. Patients with passive range of motion symmetric with the unaffected shoulder were selected for arthroscopic biceps tenotomy, if the tear was thought to be irreparable, or if they were older and not willing to participate in the rehabilitation required after rotator cuff repair. Patients were excluded from the study population if they had undergone a prior surgical procedure on the affected shoulder (23 cases) or if they did not have a minimum of 2 years' clinical and radiographic follow-up (60 cases). After enforcement of the exclusion criteria, 307 shoulders in 291 patients were available for clinical and radiographic review at a minimum of 2 years' follow-up.

Of the 307 shoulders, 175 (57.0%) were in female patients, 239 (77.9%) were dominant- sided, and 236 (76.9%) were right shoulders. The patients' age at the time of surgery averaged 64.3 years (range, 39-81 years). In 172 cases (56.0%) patients did not recall a traumatic episode initiating their symptoms; in 95 cases (30.9%) patients related a specific traumatic episode initiating shoulder problems. In 34 cases (11.1%) patients reported chronic shoulder pain that became substantially worse after a traumatic episode, and in 6 cases (2.0%) patients could not recall whether their symptoms were related to a traumatic episode. Of the cases, 30 (9.8%) involved workers' compensation. The time interval from onset of symptoms to surgery averaged 67.2 months in 288 cases (range, 3-360 months); in 19 cases, patients were unable to determine when their symptoms began. Patients received a mean of 4.6 corticosteroid injections (range, 0-30 injections) before surgery, with 205 shoulders (66.8%) receiving less than 5 injections, 71 (23.1%) receiving 5 to 10 injections, and 31 (10.1%) receiving more than 10 injections. Preoperatively, in 47 cases (15.3%) patients were heavy laborers, in 115 (37.5%) patients were moderate manual laborers, in 61 (19.9%) patients performed sedentary work, and in 28 we had no precise information about the type of work. At the time of surgery, in 165 cases (53.7%) patients reported being retired, in 69 (22.5%) patients were working, in 38 (12.4%) patients were unemployed, and in 35 (11.4%) patients had stopped working because of shoulder symptoms.

All patients in this series were evaluated preoperatively with a Constant score, which was also adjusted to reflect a percentage of what is considered normal for a given age and sex, and active mobility was evaluated.[6,7] The only rotator cuff testing consistently used during the time of this study was the dropping sign and the hornblower's sign, and therefore, these are the only clinical rotator cuff tests reported in this investigation.[49]

All shoulders had a preoperative assessment by use of fluoroscopic and magnification-controlled radiographs, including an anterior-posterior view with the arm in inter nal rotation, external rotation, and neutral rotation with the patient standing. By use of these radiographs, the acromiohumeral interval was measured.[27] In addition, arthritis was staged by use of the classification of Hamada et al[20] (Figure 1).

Secondary imaging was obtained in 254 shoulders (82.7%) and included 26 arthrograms, 172 computed tomographic arthrograms, and 56 magnetic resonance imaging studies. Fatty infiltration of the infraspinatus and subscapularis was graded according to the 3-tiered, modified classification of Goutallier et al[18] in shoulders that had preoperative computed tomographic arthrography or magnetic resonance imaging. Of the shoulders, 107 (46.9%) had minimal (stage 0 or 1) fatty infiltration of the infraspinatus, 29 (12.7%) had stage 2 infraspinatus fatty infiltration, and 92 (40.4%) had marked (stage 3 or 4) fatty infiltration of the infraspinatus. Of the shoulders, 169 (74.1%) had minimal (stage 0 or 1) fatty infiltration of the subscapularis, 28 (12.3%) had stage 2 subscapularis fatty infiltration, and 31 (13.6%) had marked (stage 3 or 4) fatty infiltration of the subscapularis. By use of either computed tomograms or magnetic resonance imaging, the teres minor muscle was categorized as being absent (7 cases), atrophic (15 cases), normal (188 cases), or hypertrophic (18 cases) (Figure 2). Atrophy and/or fatty infiltration of the supraspinatus muscle was not evaluated in this study because many of the imaging studies in this series were done before the routine performance of the sections required for proper evaluation of the supraspinatus muscle.

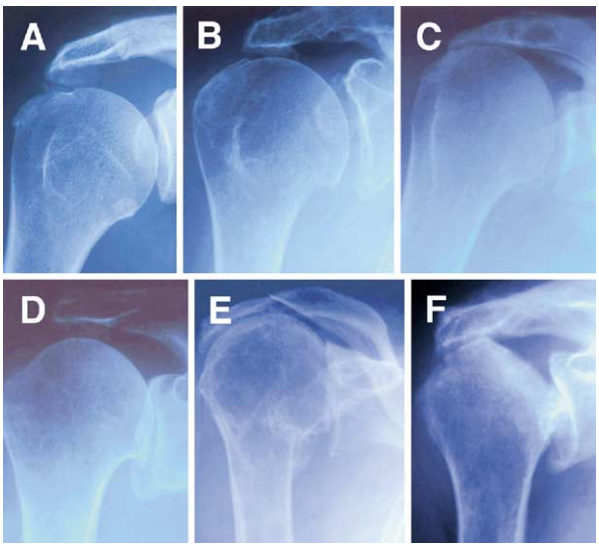

Figure 1 Classification of arthritis in chronic rotator cuff tears (Hamada et al[20]). **A**, Stage 1: Acromiohumeral interval greater than 6 mm. **B**, Stage 2: Acromiohumeral interval less than 7 mm. **C**, Stage 3: Acromiohumeral interval less than 7 mm with acetabulization of acromion. **D**, Stage 4a: Acromiohumeral interval less than 7 mm with glenohumeral arthritis without acetabulization. **E**, Stage 4b: Acromiohumeral interval less than 7 mm with acetabulization and glenohumeral arthritis. **F**, Stage 5: Acromiohumeral interval less than 7 mm with osteonecrosis of humeral head.

Figure 2 Classification of teres minor muscle: absent (**A**), atrophic (**B**), normal (**C**), or hypertrophic (**D**).

All cases underwent glenohumeral arthroscopy by use of either general anesthesia (early in the series) or interscalene anesthesia. The patients were positioned in the lateral position (early in the series) or beach-chair position. A posterior portal was used for visualization, and routine diagnostic arthroscopic examination was performed. An anterolateral working portal was used for instrumentation. Specific details of the rotator cuff tears were recorded in each case and are reported in Table 1. Biceps tenotomy was performed by simply sectioning the tendon at its origin at the supraglenoid tubercle and superior labrum. The tendon was allowed to retract out of the glenohumeral joint. In cases in which the biceps did not retract as a result of enlargement or attritional changes, the intraarticular portion of the biceps was resected to allow for retraction out of the glenohumeral joint. An associated acromioplasty was performed in patients with an anterior acromial spur and a centered head as determined on radiography (110 cases [35.8%]). An arthroscopic distal clavicular resection was done in 3 cases (1.0%) with preoperative acromioclavicular joint tenderness, and an arthroscopic coracoplasty was performed in 2 cases (0.7%) with coracohumeral impingement.

Table I Intraoperative findings

Surgical finding	No. of cases (%)
Supraspinatus tear only	95 (31.0)
Supraspinatus and infraspinatus tear	104 (33.9)
Supraspinatus and subscapularis tear	34 (11.1)
Supraspinatus, infraspinatus, and subscapularis tear	66 (21.5)
Subscapularis tear only	8 (2.6)
Biceps tendinitis	160 (52.1)
Biceps tendon subluxation	114 (37.1)
Biceps tendon dislocation	34 (11.1)

Postoperatively, the arm was placed in a simple sling. Passive range-of-motion exercises were instituted on postoperative day 1. Active mobility exercises were incorporated as tolerated by the patient. After 2 weeks, the patients were encouraged to begin a hydrotherapy and swimming program until 3 months postoperatively. Strengthening exercises were avoided to prevent development of pain and stiffness.

Follow-up evaluation was performed by an independent evaluator and consisted of the Constant score and the same mobility parameters and rotator cuff tests recorded preoperatively. The final results were determined by use of the age- and sex-adjusted Constant score as excellent (90%-100%), good (80%-89%), fair (70%-79%), or poor ($>$ 70%). In addition, patients provided a subjective assessment that was graded as excellent, good, fair, or poor based on whether they were very satisfied, somewhat satisfied, disappointed, or unhappy with their result. All shoulders had a postoperative radiographic assessment by use of fluoroscopic and magnification control with the same views as were obtained preoperatively. By use of these radiographs, the acromiohumeral interval was measured, and arthritis was staged by use of the classification of Hamada et al.[20]

Statistical analysis was performed with Fisher exact test and Pearson χ^2 test qualitative variables. When quantitative variables were evaluated, independent sample *t* test, paired sample *t* test, and 1-way analysis of variance were used. Preoperative factors potentially influencing the postoperative adjusted Constant score were further investigated by use of a multiple regression analysis. Significance was set at $P < .05$.

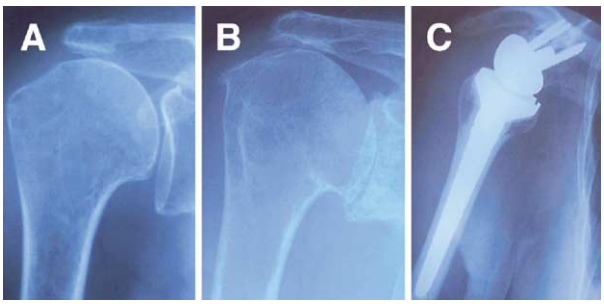

Figure 3 **A**, Radiograph of a 70-year-old woman just before arthroscopic biceps tenotomy (stage 2 arthritis). **B**, Stage 4 arthritis at 6 years' follow-up. **C**, The patient ultimately underwent shoulder replacement with a reverse-design prosthesis.

RESULTS

Follow-up averaged 57.0 months (range, 24-168 months). During the follow-up period, 9 shoulders (2.9%) underwent another operation. Two patients underwent an attempt at rotator cuff repair at another institution, because they were unhappy with their results. Both of these patients were aged 63 years at the time of biceps tenotomy, and both complained of weakness and fatigue in the affected extremity prompting them to undergo another operation. Neither patient would return for examination after the second procedure, but both said that they felt the second procedure helped them. A third patient had a traumatic glenohumeral dislocation while skiing 5 years after arthroscopic tenotomy, resulting in a complete subscapularis tear and a pseudoparalytic shoulder. The patient underwent open subscapularis repair at our institution and, at 18 months postoperatively, had good functional recovery and a Constant score of 60 points. Six older patients (mean age at time of biceps tenotomy, 70.0 years) underwent shoulder arthroplasty with a reverse- design prosthesis because of increasing pain at a mean 50.0 months (range, 36-83 months) after biceps tenotomy. Five patients had Hamada stage 4 arthritis and one had Hamada stage 5 arthritis before shoulder arthroplasty (Figure 3).

One superficial wound infection resolved with antibiotic treatment, and the patient's final result was rated as good. In 15 patients (4.9%) postoperative stiffness developed, 4 of which were subsequently diagnosed with reflex sympathetic dystrophy. Of these 15 patients, 12 were involved in either workers' compensation cases or ongoing personal injury litigation. For these 15 cases, recovery of active mobility took a mean of 9.0 months (range, 4-24 months). None required another surgical procedure to treat the stiffness. Three patients sustained a traumatic anterior glenohumeral dislocation at 30, 36, and 62 months postoperatively respectively. One of these patients underwent subscapularis repair, and the other two lost some active mobility but refused further surgical intervention.

A significant improvement occurred in all facets of the Constant score at latest follow-up (Table II). By use of the age- and sex- adjusted Constant score, 157 shoulders (51.1%) were rated as excellent, 63 (20.5%) were rated as good, 45 (14.7%) were rated as fair, and 42 (13.7%) were rated as poor. Of the shoulders, 154 (50.2%) demonstrated an obvious deformity of the biceps muscle and 98 (31.9%) had no evidence of deformity, in the remainder of cases, the examiner was undecided on whether a deformity was present (obese patients, patients with poor muscle tone). Subjectively, in 184 cases (59.9%) patients rated their result as excellent, in 80 (26.1%) patients rated their result as good, in 31 (10.1%) patients rated their result as fair, and in 12 (3.9%) patients rated their result as poor.

Radiographically, the mean acromiohumeral interval decreased during the follow- up period (Table III). In addition, arthritis as staged by use of the Hamada classification significantly progressed. Of the cases, 55 (17.9%) progressed 1 radiographic stage, 15 (4.9%) progressed 2 stages, 4 (1.3%) progressed 3 stages, and 2 (0.7%) progressed 4 stages (Figures 4-6).

Among factors investigated as potentially influencing the clinical and radiographic results, sex, work status, workers' compensation status, type of injury (traumatic vs atraumatic), bilaterality, number of preoperative injections, type of anesthesia, operative positioning, performance of concomitant distal clavicular resection, and performance of concomitant coracoplasty had no statistical influence with the numbers available. The influence of other factors on the clinical and radiographic results is shown in Table IV. Older patient age at the time of surgery negatively influenced active anterior elevation and development of arthritis. Increased time interval from onset of symptoms to surgery negatively influenced active anterior elevation, development of arthritis, and strength. Longer follow-up had a negative influence over active external rotation, strength, and radiographic results (decreased acromiohumeral interval and higher arthritic stage). Teres minor atrophy in patients with severe fatty infiltration of the infraspinatus negatively influenced many clinical and radiographic outcome parameters. By use of a multiple regression model, 3 factors appeared to be more influential over the postoperative adjusted Constant score: preoperative adjusted Constant score, fatty infiltration of the subscapularis muscle, and fatty infiltration of the infraspinatus muscle (Table V).

An acromioplasty was performed in 110 cases (35.8%). For purposes of data analysis, patients were divided into those with a preoperative acromiohumeral interval of 6 mm or less and those with a preoperative acromiohumeral interval greater than 6 mm.

Table II Preoperative and postoperative Constant scores and clinical data

	Pain (points) (Mean ± SD)	Activity (points) (Mean ± SD)	Mobility (points) (Mean ± SD)	Strength (points) (Mean ± SD)	Constant (points) (Mean ± SD)	Adjusted Constant (%) (Mean ± SD)	Active anterior elevation (°) (Mean ± SD)	Active external rotation (°) (Mean ± SD)	Internal rotation (vertebrae)	Positive dropping sign (%)	Positive hornblower's sign (%)
Preoperative	3.4 ± 2.4	7.3 ± 3.1	31.5 ± 8.6	6.0 ± 4.1	48.4 ± 13.6	63.6 ± 17.9	153.4 ± 40.4	44.8 ± 25.0	L1	29.0	7.2
Postoperative	11.0 ± 3.2	14.9 ± 4.5	35.3 ± 6.2	6.4 ± 4.5	67.6 ± 14.7	88.9 ± 19.7	164.6 ± 25.4	36.2 ± 26.8	T12	41.7	10.4
P value	< .0001	< .0001	< .0001	.0420	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001

Table III Preoperative and postoperative radiographic data

		Arthritis classification (Hamada et al[20])				
	Acromiohumeral interval (mm) (Mean ± SD)	Stage 1 (%)	Stage 2 (%)	Stage 3 (%)	Stage 4 (%)	Stage 5 (%)
Preoperative	6.6 ± 2.7	54.4	36.2	6.8	2.6	0.0
Postoperative	5.3 ± 2.9	39.7	39.5	11.7	6.8	2.3
P value	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001

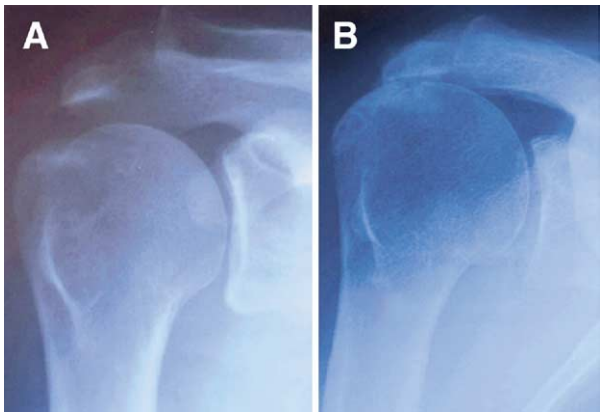

Figure 4 A, Radiograph of a 59-year-old man just before arthroscopic biceps tenotomy (stage 1 arthritis). **B**, Stage 3 arthritis at 13 years' follow-up.

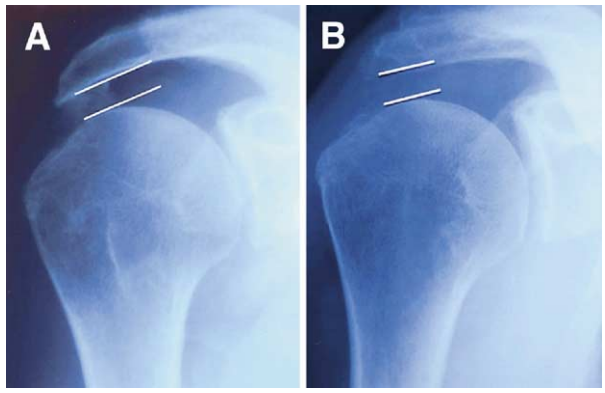

Figure 5 A, Radiograph of a 60-year-old woman just before arthroscopic biceps tenotomy and acromioplasty (stage 1 arthritis). **B**, No progression of the arthritis has occurred at 9 years' follow-up.

Of the shoulders with a preoperative acromiohumeral interval of 6 mm or less, 18 cases underwent concomitant acromioplasty, and 122 cases did not have an acromioplasty. In this situation, postoperative gains in the mobility component of the Constant score (4.8 points vs –0.4 points, $P = .0400$) and active anterior elevation (17.6° vs –3.8°, $P = .0030$) favored not performing an acromioplasty. Of the shoulders with a preoperative acromiohumeral interval of greater than 6 mm, 92 cases underwent concomitant acromioplasty, and 75 did not have an acromioplasty. When the acromiohumeral interval was greater than 6 mm preoperatively, the pain component of the Constant score ($P = .0090$), the gain in the pain component of the Constant score ($P = .0400$), the activity component of the Constant score ($P = .0100$), the gain in the activity component of the Constant score ($P = .0200$), the mobility component of the Constant score ($P = .0030$), the strength component of the Constant score ($P < .0001$), the gain in the strength component of the Constant score ($P = .0070$), and active anterior elevation ($P = .0100$) all favored performance of a concomitant acromioplasty. Performance of an acromioplasty was found to have no further influence on the clinical or radiographic results with the numbers available.

DISCUSSION

This study demonstrates that, in selected cases, arthroscopic biceps tenotomy yields favorable clinical results in the treatment of full-thickness rotator cuff

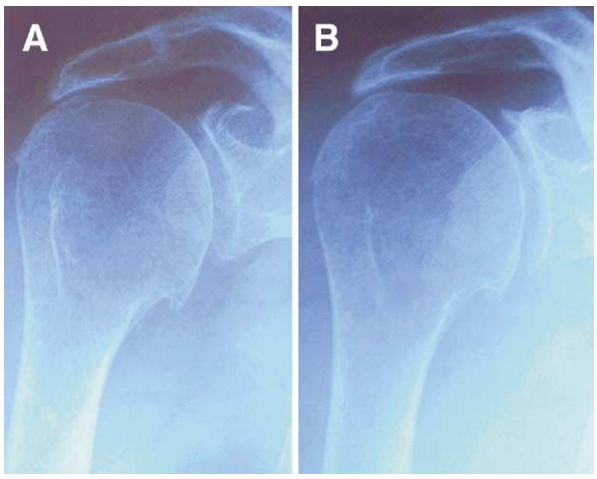

Figure 6 **A**, Radiograph of a 67-year-old woman just before arthroscopic biceps tenotomy (stage 3 arthritis). **B**, No progression of the arthritis has occurred at 6 years' follow-up.

tears. Despite these encouraging clinical results, arthroscopic tenotomy does not appear to alter the progressive radiographic changes that occur with long-standing rotator cuff tears.

The first point of discussion must focus on why, in selected cases, rotator cuff repair is not possible and/or desirable. Our indications in performing biceps tenotomy in lieu of rotator cuff repair were based on technical reparability of the rotator cuff and patient motivation and willingness to undergo postoperative rehabilitation required after rotator cuff repair. The concept of what constitutes a technically repairable rotator cuff tear has been extensively discussed by Gartsman et al[12,13] and Gerber et al,[16] who have noted that this concept differs among authors and has been based on clinical, radiographic, and intraoperative criteria. At the beginning of our experience with arthroscopic biceps tenotomy in the treatment of rotator cuff tears, we judged reparability based on the acromiohumeral interval (< 7 mm contraindicated repair).[8,47,48,52] More recently, fatty infiltration of the rotator cuff has been found to be an important prognosticator in rotator cuff surgery and a major contributor to superior humeral migration.[18,19,36] Therefore, in our practice, rotator cuff reparability is largely determined by the presence of superior migration of the humeral head on radiographs and/or the presence of fatty infiltration of the rotator cuff musculature on secondary imaging studies.

The second criterion required for successful rotator cuff repair is to have sufficient patient motivation to perform the necessary postoperative course of rehabilitation. Intimately associated with the required patient motivation is patient age. Although some authors have shown that the results of rotator cuff repair are independent of age, other investigators have demonstrated that the results tend to be poorer in patients aged over 65 years.[22,43] Anecdotally, our older patients with rotator cuff tears seem more apprehensive about the rehabilitation and convalescence required after rotator cuff repair. Therefore, patient motivation and patient age play a large role in patient selection for rotator cuff repair. A comparison of mean patient age in this series of arthroscopic biceps tenotomy with series of rotator cuff repair in the literature illustrates our use of age in the selection of patients in whom we believe arthroscopic tenotomy is more appropriate than rotator cuff repair (Table VI). In addition, patients in this series of arthroscopic biceps tenotomy were older, with a higher percentage of women than most series of rotator cuff repairs, perhaps indicating a lower functional demand (Table VI).

The second point of discussion in this study focuses on the rationale for biceps tenotomy. Early in our arthroscopic experience, like other authors, we used arthroscopic acromioplasty in the treatment of rotator cuff tears in patients who were considered poor candidates for repair. Experience taught us that many of our patients with chronic rotator cuff tears had a dramatic improvement in their shoulder symptoms shortly after the long head of the biceps tendon spontaneously ruptured. A review of the literature shows that most authors advocate nonoperative treatment of spontaneous rupture of the long head of the biceps, the results of which are favorable.[28,30,33,34,44,51] Furthermore, to our knowledge, only one report exists in the literature on the surgical treatment of spontaneous rupture of the long head of the biceps tendon, despite this tendon being the most frequently ruptured tendon in human beings.[28,30,45,51] The paucity of reports on surgical repair of a ruptured long head of the biceps tendon serves further to confirm the satisfactory results obtained with nonoperative treatment.

Biceps tenotomy was initially criticized based on biomechanical data suggesting the role of the long head of biceps as a humeral head depressor and shoulder stabilizer.[10,25,26,41] Furthermore, some surgeons were of the opinion that a ruptured long head of the biceps tendon would exacerbate subacromial impingement.[33,34] Rockwood et al[40] have suggested that results of debridement of chronic rotator cuff tears are better in the absence of a preoperative rupture of the long head of the biceps. Warner and McMahon[50] have shown that biceps tenodesis decreased the acromiohumeral interval in patients with subacromial impingement syndrome; however, all patients in their series also underwent acromioplasty. Studies that have attempted to correlate bicipital pathology with results of debridement of rotator cuff tears have only looked at the preoperative condition of the biceps tendon. Given the natural history of pain relief after biceps rupture, it seems more reasonable to correlate the operative results with the condition of the biceps tendon at latest follow-up; to our knowl-

Table IV Statistically significant influence of various factors on postoperative results

Parameter	*P* value					
	Age at time of surgery	Delay to surgery	Length of follow-up	Teres minor status	Fatty infiltration of infraspinatus	Fatty infiltration of subscapularis
Pain					.0080	.0200
Activity					< .0001	.0020
Mobility						<.0001
Strength		.0100	< .0001	.0100	< .0001	.0020
Constant					< .0001	< .0001
Adjusted Constant					< .0001	< .0001
Active anterior elevation	.0200	< .0001				
Active external rotation			.0100	< .0001	< .0001	
Dropping sign					< .0001	.0400
Hornblower's sign				< .0001	< .0001	
Acromiohumeral interval			< .0001	.0020	< .0001	.0010
Hamada arthritis stage	.0030	< .0001	< .0001	.0010	< .0001	< .0001
Subjective result					.0020	

*Only significant in patients with severe fatty degeneration of the infraspinatus.

Table V Multivariate linear regression analysis of factors influencing postoperative adjusted Constant score

Parameter	Correlation coefficient	*P* value
Constant score	66.434	< .0001
Preoperative adjusted Constant score	0.471	< .0001
Subscapularis fatty infiltration	–13.317	< .0001
Infraspinatus fatty infiltration	–9.696	< .0001

edge, no study has done this. Despite concerns and criticisms expressed by some investigators, our early results, as well as the results of others, have been encouraging, prompting the continued use of biceps tenotomy in this select group of patients.[17,38,48]

The third point of discussion focuses on the results of biceps tenotomy in this patient population. Even with a mean follow-up of 57 months postoperatively, pain relief and functional improvement have remained favorable after biceps tenotomy. Interestingly, fatty infiltration of the rotator cuff negatively influences the results of arthroscopic biceps tenotomy just as with rotator cuff repair. Use of a concomitant acromioplasty is advisable in patients with a normal acromiohumeral interval but may be detrimental in patients with preoperative proximal migration of the humeral head. Our results have further shown that, at a mean follow-up approaching 5 years, the complication rate and reoperation rate with biceps tenotomy are acceptably low, with only 1% of patients undergoing a subsequent attempt at rotator cuff repair and less than 2% requiring further surgery for cuff tear arthropathy. At follow-up, no deformity associated with biceps tenotomy was identifiable in approximately half of the patients. Furthermore, no patient characterized their result as fair or poor based on cosmesis. Our mean patient age, 10 to 15 years older than that in series of traumatic or spontaneous biceps rupture, may explain the observed tolerance to this cosmetic finding.[28,51] We have noted that our patients aged 45 to 55 years become concerned about deformity after spontaneous rupture of the long head of the biceps tendon. After 65 years of age, however, we have rarely found it necessary to treat a spontaneous rupture of the long head of the biceps tendon. In these older patients, the characteristic deformity may not occur because of muscle atrophy and age related loss of muscle tone and definition.

Functionally, Mariani et al[28] and Soto-Hall and Stroors[45] reported a 20% loss of forearm supination strength and an 8% to 20% loss of elbow flexion strength in patients with ruptures of the long head of the biceps tendon. They also noted patient complaints of discomfort and muscle cramping with resisted elbow flexion and forearm supination (turning a screwdriver). We did not note these specific complaints in our patients and performed no strength testing of the elbow and forearm. Because of concerns regarding poor cosmesis and decreased elbow and forearm strength, we are hesitant to recommend biceps tenotomy in patients aged younger than 55 years. In this series, in only 24 cases were patients aged younger than 55 years. Some authors have proposed arthroscopic biceps tenodesis as an alternative to arthroscopic biceps tenotomy in patients with an irreparable rotator cuff tear to avert cosmetic deformity.[3] Indeed, it is fortunately rare that a younger patient is a candidate for biceps tenotomy; most young patients do not have irreparable tears and/or severe fatty infiltration of the rotator cuff musculature, and most are willing to undergo the rehabilitation required after

Table VI Epidemiologic comparison of massive rotator cuff tear repair (literature) and arthroscopic biceps tenotomy (present series)

Study	Procedure	No. of cases	Mean age at surgery (y)	Female patients (%)
Walch et al[47]	Open repair	67	54	21
Gazielly et al[14]	Open repair	100	56	38
Bellumore et al[2]	Open repair	108	55	33
Gerber et al[16]	Open repair	27	56	33
Rokito et al[42]	Open repair	30	57	30
Galatz et al[11]	Open repair	33	55	23
Augereau and Gazielly[1]	Open repair	671	57	42
Present series	Arthroscopic biceps tenotomy	307	64	57

rotator cuff repair. In this age group, we generally recommend rotator cuff repair with biceps tenodesis, if necessary.

Another point of discussion is the radiographic development of arthritis and change in the acromiohumeral interval in our patients. The development of both acromiohumeral and glenohumeral arthritis seems to be a legitimate concern when treating patients with rotator cuff tears with biceps tenotomy without repair of the rotator cuff. Development of true rotator cuff tear arthropathy, as described by Neer et al,[32] is not inevitable in patients with massive rotator cuff tears, however, occurring in only 4% of patients with massive rotator cuff tears. Hamada et al[20] established a classification system for arthritis occurring in patients with massive rotator cuff tears. According to this classification, 21.5% of our cases progressed at least 1 radiographic stage. The presence of acromiohumeral arthritis (stage 3) increased from 6.8% preoperatively to 11.1% postoperatively. The presence of glenohumeral arthritis (stage 4) increased from 2.6% preoperatively to 6.5% postoperatively. The presence of osteonecrosis of the humeral head (stage 5), which was absent preoperatively in all cases, appeared in 2.3% of shoulders postoperatively. These findings would suggest that arthroscopic biceps tenotomy does not alter the natural radiographic arthritic progression known to occur in shoulders with chronic rotator cuff tears.

Similarly, in our series, the mean acromiohumeral interval decreased during the follow-up period. Tenotomy of the long head of the biceps tendon could potentially be implicated as a contributing factor to the observed decrease in the acromiohumeral interval, however, we have never observed immediate superior migration of the humeral head on postoperative radiographs after biceps tenotomy. Nové-Josserand et al[36] have shown that rupture of the long head of the biceps tendon did not statistically influence the acromiohumeral interval in 264 shoulders with rotator cuff tears. They also discovered that fatty infiltration of the infraspinatus has the greatest influence over the acromiohumeral interval, a finding confirmed by our study.

In summary, arthroscopic biceps tenotomy yields favorable clinical results in patients with full-thickness rotator cuff tears in whom repair is not possible and/or desirable. Second, arthroscopic biceps tenotomy carries a low complication and reoperation rate. Third, fatty infiltration of the rotator cuff negatively influences the results of arthroscopic biceps tenotomy just as with rotator cuff repair. Finally, despite encouraging clinical results of arthroscopic biceps tenotomy, the natural progressive radiographic changes that occur with long-standing rotator cuff tears are unaltered.

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