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Repairs of the Rotator Cuff

CORRELATION OF FUNCTIONAL RESULTS WITH INTEGRITY OF THE CUFF*

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ABSTRACT: We evaluated the results of 105 operative repairs of tears of the rotator cuff of the shoulder in eighty-nine patients at an average of five years postoperatively. We correlated the functional result with the integrity of the cuff, as determined by ultrasonography. Eighty per cent of the repairs of a tear involving only the supraspinatus tendon were intact at the time of the most recent follow-up, while more than 50 per cent of the repairs of a tear involving more than the supraspinatus tendon had a recurrent defect. Older patients and patients in whom a larger tear had been repaired had a greater prevalence of recurrent defects.

At the time of the most recent follow-up, most of the patients were more comfortable and were satisfied with the result of the repair, even when they had sonographic evidence of a recurrent defect.

The shoulders in which the repaired cuff was intact at the time of follow-up had better function during activities of daily living and a better range of active flexion (129 ± 20 degrees compared with 71 ± 41 degrees) compared with the shoulders that had a large recurrent defect. Similar correlations were noted for the range of active external and internal rotation and for strength of flexion, abduction, and internal rotation. In the shoulders in which the cuff was not intact, the degree of functional loss was related to the size of the recurrent defect.

The function of the patients who had an intact cuff after a repair of a large tear was as good as that of the patients who had an intact cuff after a repair of a small tear.

The goal of this study was to correlate the functional outcome of repairs of the rotator cuff with the integrity of the repaired cuff at the time of follow-up. This investigation is important because it has been observed that some patients who have an untreated tear of the rotator cuff have relatively good and comfortable function of the shoulder, that subacromial decompression alone can yield a good result when repair of the cuff is impossible, and that a good functional result can follow an attempted repair of the cuff even when

postoperative arthrograms show a defect in the cuff^{3,19,22,24}.

Arthrography, magnetic resonance imaging, arthroscopy, and so-called second-look operations are not practical for the investigation of the integrity of a series of repaired rotator cuffs. We selected ultrasonography for this study because it is quick, painless, inexpensive, non-invasive, and harmless with regard to ionizing radiation. Most importantly, an investigator who is experienced with sonography can determine accurately whether each of the tendons composing the rotator cuff is intact^{4,7,14,17,18}. Mack et al.¹⁵ and Crass and Craig⁵ demonstrated the effectiveness of ultrasonography in the evaluation of the postoperative status of the rotator cuff after an operative repair.

Methods

Every patient in this study had a chronic tear of the rotator cuff that had been repaired by, or under the direct supervision of, one of us (F. A. M., III). All of the operations included an anterior-inferior acromioplasty¹⁹. The involved tendon or tendons were mobilized as necessary. An osseous trough was created in the humerus, and it was used to reattach the mobilized tendons. The site of reattachment was usually in the sulcus, adjacent to the humeral articular surface; however, if, after section, the tendons did not reach their original anatomical attachment without undue tension when the arm was at the side, the trough was made somewhat more medially. The cuff was protected from active use for three months postoperatively.

Because the attainment of maximum strength of the shoulder after repair of a cuff may take more than a year, only patients who had been followed for more than two years were included in our study^{2,26,27}.

At the time of the most recent follow-up, ultrasonography was performed by one of two of us (L. A. M. and K. Y. W.), experts at performing these studies on the shoulder, who were unaware of the details of the operative procedure or the current status of the patient. The tests were performed with a 7.5-hertz linear-array transducer (model 128; Acuson, Mountainview, California), and a standard technique, which has been previously described in detail¹³, was used. By careful positioning and by use of specific passive motions, we could determine the integrity of each tendon (the subscapularis, biceps, supraspinatus, infraspinatus, and teres minor).

The size of a defect in a cuff can be recorded in terms

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of length or area or with terms such as small or massive. We characterized the status of the cuff in terms of the integrity of the different tendons. Type 0 refers to an intact cuff, and Type 1A, to the mildest identifiable pattern of deficiency — that is, thinning or a partial-thickness defect of the supraspinatus tendon. Type 1B refers to a full-thickness defect of the supraspinatus tendon; Type 2, to a full-thickness defect involving the supraspinatus and infraspinatus tendons; and Type 3, to a full-thickness defect involving the supraspinatus, infraspinatus, and subscapularis tendons. All of the tears in this series, as seen at operation and on ultrasonography, could be characterized with this simple scheme. The type of tear that was found at operation was called the operative type, and the type that was revealed by ultrasonography at the time of follow-up was called the follow-up type.

Functional Examination

A key element of our study was measurement of the function of the involved shoulder at the time of follow-up. Without knowledge of the operative or ultrasonographic findings, an independent examiner (S. E. J.) evaluated all of the patients, using the system of the American Shoulder and Elbow Surgeons¹, at the time of follow-up. Patients were asked to rate their comfort, as well as their satisfaction with the result of the operation, on a scale of 0 to 5. Selected ranges of active and passive motion were also recorded. Patients were asked to demonstrate their ability to perform thirteen functions: (1) reaching the back pocket, (2) washing the opposite axilla, (3) combing the hair, (4) using the hand overhead, (5) using the extremity to pull, (6) using the arm to dress, (7) sleeping on the involved side, (8) using the extremity in perineal care, (9) using the extremity for eating with a utensil, (10) reaching with the elbow at the level of the shoulder, (11) carrying 4.5 to 6.8 kilograms (ten to fifteen pounds) at the side, (12) using the extremity to lift a weight, and (13) using the extremity to throw a ball.

We also made isometric measurements of the strength of selected muscles during certain actions of the shoulder. The measurements, recorded in kilograms force, were made with a hand-held upper-extremity dynamometer (Spark Instruments and Academics, Coralville, Iowa). The strength of external and internal rotation and of extension were measured with the arm at the side and the elbow flexed to 90 degrees. The strength of flexion was measured with the arm flexed 90 degrees in the sagittal plane without rotation, and the strength of abduction was measured with the arm abducted 90 degrees. For the purpose of comparison, the shoulders were grouped according to the sex of the patient. Although data on both shoulders were collected for comparison of the treated and the contralateral limbs, the high prevalence of disease of the contralateral rotator cuff precluded use of that side for meaningful comparison.

Statistical Analysis

Age, strength, and range of motion were analyzed with standard analysis of variance for factorial grouping²⁸. Sta-

tistical significance (95 per cent confidence level) was determined with the Scheffé F test²⁸. Non-parametric analysis was used when appropriate (for example, for evaluation of the ability to perform activities of daily living); the Mann-Whitney U test was used for comparing two groups; and the Kruskal-Wallis test, for comparing three or more independent groups^{25,28}.

Material

Between October 1977 and January 1988, 216 repairs of the rotator cuff were done in 186 patients by the Shoulder and Elbow Service of the University of Washington. We were able to perform minimum two-year follow-up studies on eighty-nine of these patients (105 tears) who met the criteria for inclusion in our study — that is, they were all operated on by the same one of us, or under his supervision; all tendons of the cuff had been repaired directly to bone without transfer of tissue or use of interpositional grafts; and the description of the tear of the cuff was adequate for determination of the operative type.

There had been no previous attempt to repair the cuff in eighty-six (82 per cent) of the shoulders. In nineteen shoulders, a second or a recurrent tear was repaired after a previous repair. The average time between the initial and repeat repairs was two years (range, five months to eleven years). In this study, each shoulder was included only once: either in the group in which a secondary repair had been done or in the group in which a primary repair had been done. All shoulders that needed a repeat repair were evaluated only after the last repair that was performed by one of us (F. A. M., III). The distribution of primary and repeat repairs was similar for each operative type. We analyzed the results of the primary and repeat repairs both together and separately.

At the time of repair, the ages of the patients averaged sixty years (range, thirty-two to eighty years). One operation had been done in a patient who was between thirty and thirty-nine years old; sixteen, in patients who were between forty and forty-nine; thirty-one, between fifty and fifty-nine; forty-two, between sixty and sixty-nine; fourteen, between seventy and seventy-nine; and one, between eighty and eighty-nine. There was a significant correlation between the size of the tear as seen at the time of the operation and the age of the patient (Table I). The patients who had an operative type-1A (partial-thickness) or type-1B (supraspinatus) tear were significantly younger ($p < 0.0001$) than those who had a bigger tear. Sixty-seven per cent of the tears were in men, and this sex distribution was uniform for all four types of tears. Sixty-seven per cent of the tears involved the dominant shoulder, and seventy-eight of the 105 repairs were in right-hand-dominant patients. There was no significant correlation between either hand-dominance or the sex of the patient and the integrity of the repair at the time of follow-up, the functional outcome, or the satisfaction of the patient.

Thirty-four (38 per cent) of the eighty-nine patients had a previous repair of the contralateral rotator cuff. How-

TABLE I
FUNCTIONAL RESULTS ACCORDING TO OPERATIVE TYPE

Operative Type	No. of Shoulders	Age at Repair* (Yrs.)	Average Active Motion at the Time of Follow-up (Degrees)			
			Flexion†	External Rotation		Internal Rotation at 0 Degrees of Abduction‡
				At 0 Degrees of Abduction†	At 90 Degrees of Abduction†	
Type 1A	6	49 ± 13	126	38	68	T8
Type 1B	49	57 ± 8	129	40	70	T7
Type 2	28	64 ± 8	119	28§	60	T8
Type 3	22	64 ± 8	92§	33	60	T10§

* Mean and standard deviation.

† Standard deviations of less than 10 degrees.

‡ T = the thoracic level of the spinous process that the patient could touch with the tip of the thumb.

§ Significantly different, at the 95 per cent confidence level, from the other types in the same group (see text).

ever, in only fourteen of these patients did both repairs meet the criteria for inclusion in this study.

An associated tear of the long head of the biceps tendon was documented at the operation in thirty-two (31 per cent) of the 105 shoulders. Only 23 per cent of the shoulders in which the tear was limited to the supraspinatus and infraspinatus tendons had a tear of the biceps as seen at the operation, but 59 per cent of those in which the tear involved the subscapularis as well (operative type 3) had a concomitant bicipital tear.

Results

Correlation of the Operative Type with the Follow-up Type

We compared the size of the tear at the time of the repair (the operative type) with the presence and extent of a recurrent defect in the cuff as determined with ultrasonography (the follow-up type). A substantial number of recurrent defects were found in the shoulders in which the tear had been large (operative type 2 or 3) (Table II). Fewer than one-third of the cuffs in which a tear involving three tendons (operative type 3) had been repaired were intact at the time of the latest follow-up (Table II). Older patients

and patients who had had a large tear at the time of the repair had a larger recurrent defect at the latest follow-up (Fig. 1). The average age of the patients who had a large recurrent defect (follow-up type 3) was older than that of the patients who had an intact rotator cuff or a partial-thickness lesion (follow-up type 0 or 1A). Older patients were also found to have a higher prevalence of recurrent defects (Fig. 2).

Correlation of the Operative Type with the Functional Result

We correlated the size of the tear at the time of the repair (the operative type) with the functional outcome (Table I). In general, shoulders in which the tear had been large at the time of repair had less active motion at the time of follow-up. For example, shoulders in which the tear had involved the supraspinatus, infraspinatus, and subscapularis tendons (operative type 3) had less active flexion ($p < 0.0002$) and internal rotation ($p < 0.009$) at the time of follow-up than the shoulders in any other group. Also, active external rotation at 0 degrees of abduction was significantly more limited ($p < 0.03$) for the shoulders in which the tear had involved the supraspinatus and infraspinatus tendons

TABLE II
INTEGRITY OF THE ROTATOR CUFF AT THE MOST RECENT FOLLOW-UP, ACCORDING TO OPERATIVE TYPE

Operative Type	No. of Repairs			Follow-up Type (No.)					Intact Cuffs* (Per cent)	Duration of Follow-up† (Yrs.)
	Primary	Repeat	Total	Type 0	Type 1A	Type 1B	Type 2	Type 3		
Total	86	19	105	40	28	12	14	11	65	5 (2-11)
Type 1A	5	1	6	4	2	0	0	0	100	2.7 (2-6)
Type 1B	39	10	49	23	16	3	5	2	80	5.1 (2-10.5)
Type 2	25	3	28	7	9	6	5	1	57	5.9 (2-6)
Type 3	17	5	22	6	1	3	4	8	32	4.1 (2-11)
Intact at follow-up	60	8	68							

* The rotator cuffs in which the tear was small (operative types 1A and 1B) were much more likely to be intact at the time of follow-up than those in which the tear was larger (operative types 2 and 3). The prevalence of recurrent defects was greater after repeat repairs of the rotator cuff (58 per cent) than after primary repairs (30 per cent).

† Mean, with range in parentheses.

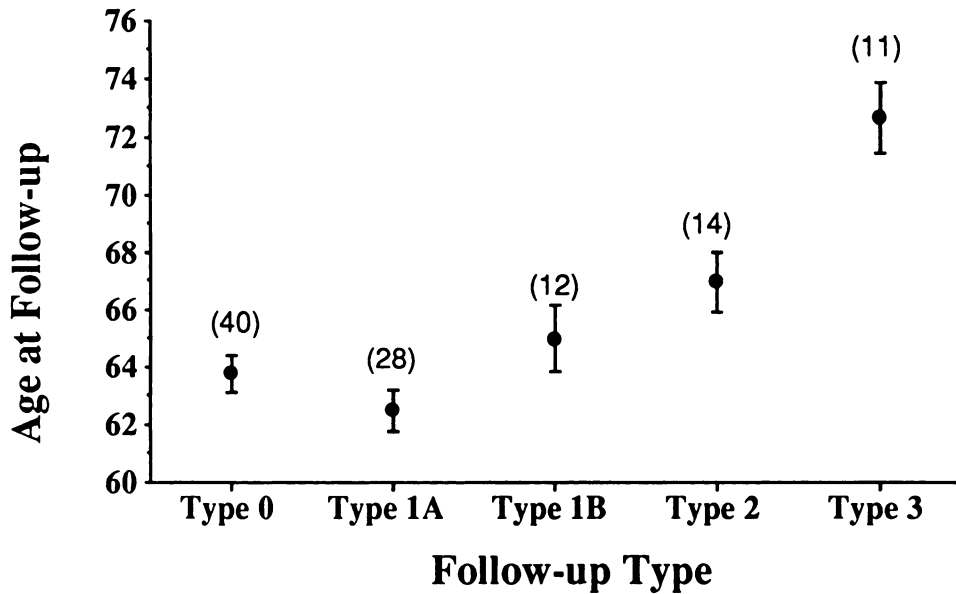


FIG. 1

Distribution of age (mean and standard error of the mean) at the time of follow-up, according to follow-up type. The numbers of shoulders are in parentheses.

compared with the other shoulders. However, there was no significant correlation between the operative type and active external rotation at 90 degrees of abduction or between the operative type and the passive ranges of horizontal adduction, flexion, or external rotation. Finally, the operative type did not significantly affect the strength of flexion, extension, internal rotation, external rotation, or abduction.

Using non-parametric statistical analysis, we found that the patient's ability to perform various activities of daily living at the latest follow-up correlated in only a minor way with the operative type of tear. Patients who had an operative type-3 lesion had a diminished ability to wash the opposite axilla ($p < 0.002$) and use the hand overhead ($p < 0.01$). For all other activities of daily living, there was no significant difference among the various types of tears.

The severity of pain at the time of follow-up and the degree of the patient's satisfaction with the result of the operative procedure did not correlate significantly with the operative type.

Correlation of the Follow-up Type with the Functional Result

We also correlated the integrity of the cuff at the time of follow-up with the quality of the functional result (Table I). The passive range of flexion averaged 145 ± 16 degrees (mean and standard deviation) for all groups; it did not correlate significantly with the follow-up type. The shoulders in which a full-thickness recurrent defect (follow-up type 0 or 1A) was identified had significantly better active flexion ($p < 0.0001$) than did the shoulders in which no

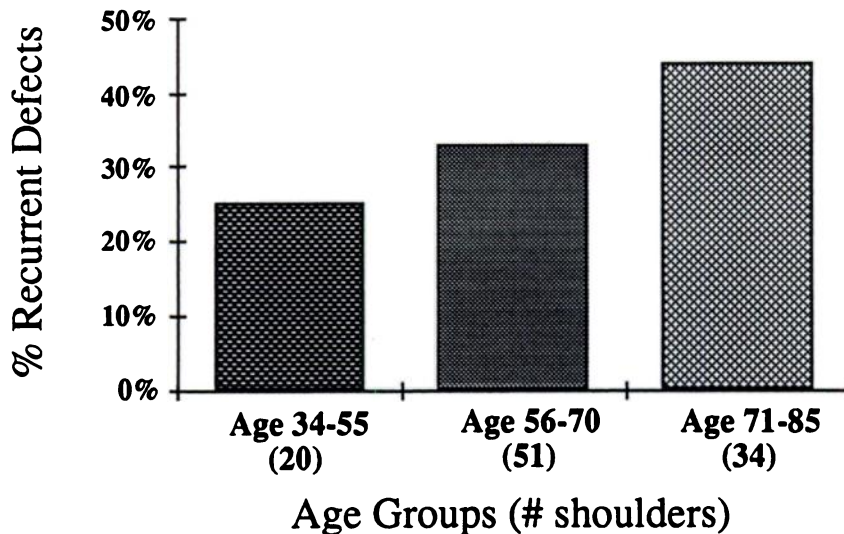


FIG. 2

The prevalence of recurrent defects according to age.

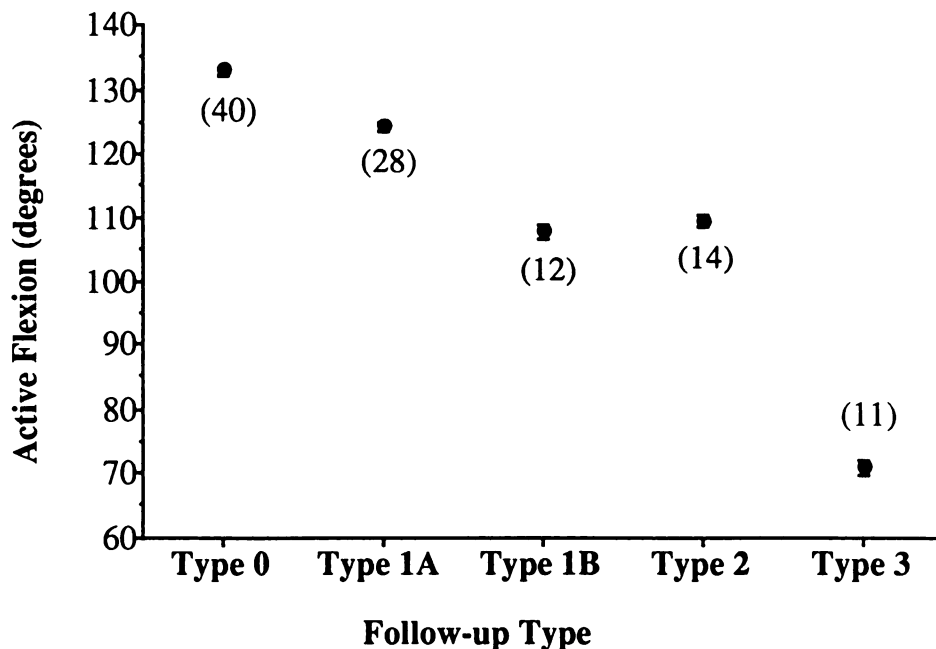


FIG. 3

Active flexion (mean and standard error of the mean), according to follow-up type. The numbers of shoulders are in parentheses.

such defect was found. The shoulders in which the recurrent defect was the most severe (follow-up type 3) had significantly less active flexion than any other group did ($p < 0.0001$, Fig. 3). Similar correlations were noted between the follow-up type and active internal rotation ($p > 0.005$), active external rotation at 0 degrees of abduction ($p > 0.02$), and active external rotation at 90 degrees of abduction ($p < 0.001$). In both men and women, an intact rotator cuff correlated with strength of flexion that was significantly better than that associated with any type of tear ($p < 0.0001$ for men and $p < 0.05$ for women, Fig. 4). The follow-up type similarly correlated with strength of abduction ($p <$

0.0002), external rotation ($p < 0.05$), and internal rotation ($p < 0.03$) in men and with strength of extension ($p < 0.02$) in women. Only strength of abduction, external rotation, and internal rotation in women did not correlate with the follow-up type.

Shoulders in which the repaired cuff was intact (type 0) at the time of the latest follow-up were significantly more functional than those in which there was a recurrent defect (Fig. 5). There was a highly significant correlation between the follow-up type and the ability to comb the hair ($p < 0.0001$), to reach with the elbow at the level of the shoulder ($p < 0.0001$), to use the elbow and hand overhead ($p <$

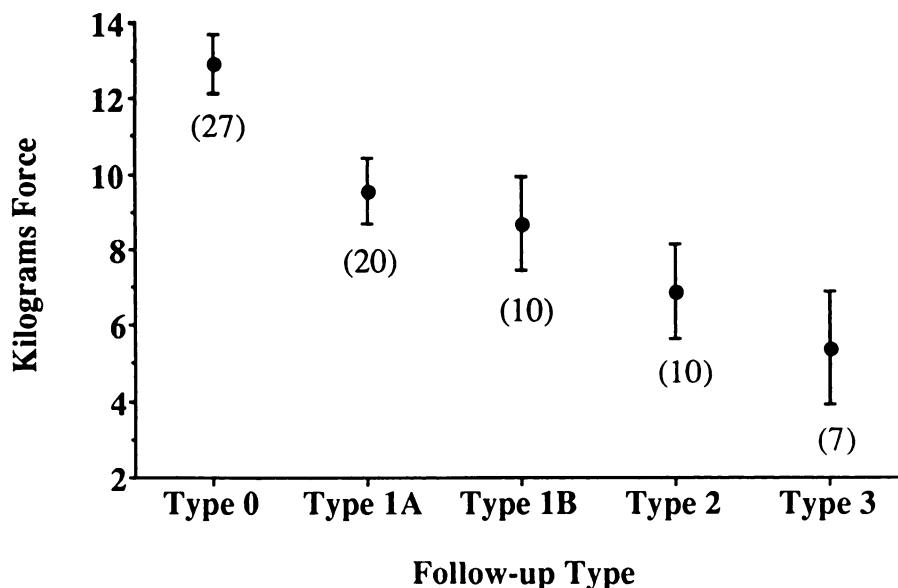


FIG. 4

Isometric strength in flexion (mean and standard error of the mean) of the shoulders of men, according to follow-up type. The numbers of shoulders are in parentheses.

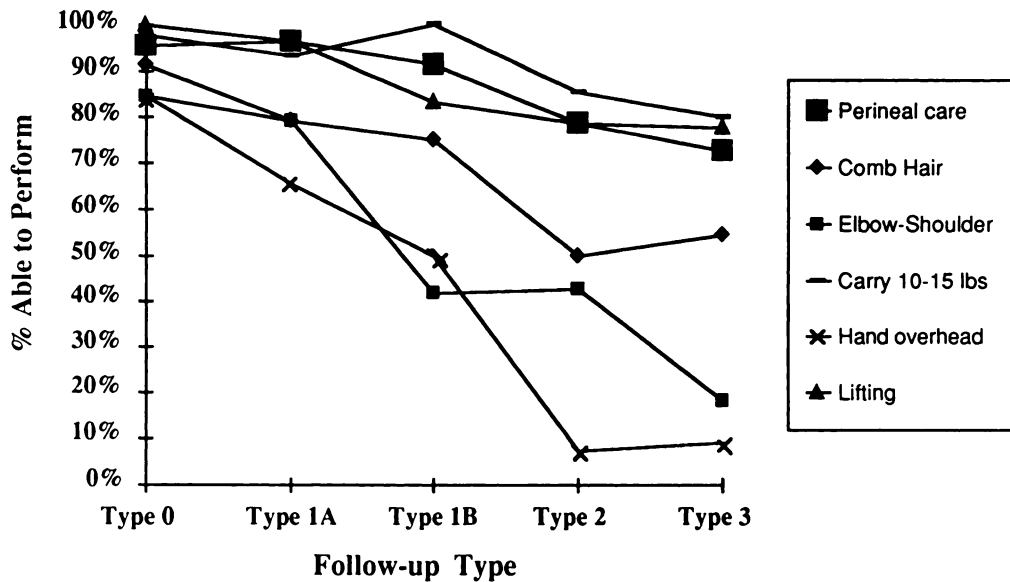


FIG. 5

The ability to perform activities of daily living, according to follow-up type. The ordinate indicates the percentage of shoulders that were functional enough for the patient to perform the activity.

0.0001), to pull ($p < 0.0005$), and to perform usual work ($p < 0.0005$). There was a less significant correlation between follow-up type and ability to perform perineal care ($p < 0.01$), lift ($p < 0.01$), dress ($p < 0.02$), carry 4.5 to 6.8 kilograms (ten to fifteen pounds) at the side ($p < 0.02$), or eat with a utensil ($p < 0.03$). The ability to reach the back pocket, wash the opposite axilla, sleep on the involved side, throw, or participate in a usual sports activity did not correlate significantly with follow-up type.

Although pain was relieved in at least 70 per cent of the shoulders in each group, the average scores for pain and for the satisfaction of the patient were distinctly better when the rotator cuff was intact (follow-up type 0) than when it was not (Table III).

Comparison of Primary and Repeat Repairs of the Rotator Cuff

The prevalence of recurrent defects was greater in the shoulders in which a repeat repair had been done (Table II).

As a group, the patients who had had a repeat repair had less strength of flexion compared with those who had had a primary repair (six compared with nine kilograms of flexion force by dynamometer). Although the patients who had had a repeat repair had a decreased average range of active flexion (105 ± 40 degrees) compared with those who had had a primary repair (121 ± 31 degrees), the difference was not statistically significant. However, the shoulders in which the cuff was intact after a repeat repair functioned as well as those in which the cuff was intact after a primary repair (Fig. 6). The data on strength, motion, comfort, and daily function were not different after the primary and repeat repairs.

Discussion

A principal purpose of this study was to investigate the correlation between the integrity of the rotator cuff and the function of the shoulder at the time of follow-up after a repair. We know of only two previous attempts at such a

TABLE III
FUNCTIONAL RESULTS ACCORDING TO FOLLOW-UP (SONOGRAPHIC) TYPE

Follow-up Type	No. of Shoulders	Average Active Motion at the Time of Follow-up* (Degrees)				No. of Painless Shoulders	Patient Satisfied (No. of Shoulders)
		Flexion†	External Rotation		Internal Rotation at 0 Degrees of Abduction‡		
			At 0 Degrees of Abduction†	At 90 Degrees of Abduction†			
Type 0	40	132	41	71	T7	37	39
Type 1A	28	124	38	68	T7	21	23
Type 1B	12	107	34	63	T8	8	12
Type 2	14	109	25	48	T9	10	10
Type 3	11	71	27	61	T10	8	10
Total	105					84	94

* See text for statistical correlations.

† Standard deviations of less than 10 degrees.

‡ T = the thoracic level of the spinous process that the patient could touch with the tip of the thumb.

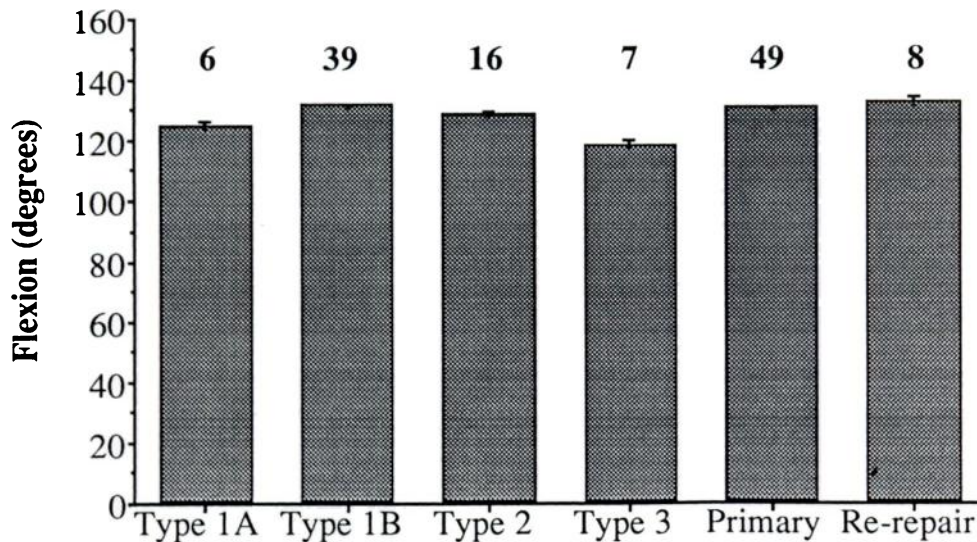


FIG. 6

Active flexion of the shoulders in which the repaired cuff was intact, according to operative type.

correlation, and these studies involved few patients and led to conflicting conclusions. Lundberg used arthrography to follow twenty-one shoulders in which the cuff had been repaired, and he found that contrast medium leaked from the cuff in seven. The results for the shoulders in which there was leakage were not as good as those for the other shoulders. Calvert et al. made double-contrast arthrograms for twenty patients at an average of thirty months after repair. In seventeen of the twenty shoulders, the contrast medium leaked into the bursa, indicating a persistent defect in the cuff. These defects were estimated to be small in eight of the shoulders, medium-sized in eight, and large in two. However, seventeen patients had complete relief of pain, fifteen had a full range of elevation of the shoulder, and ten believed that they had regained full function. Therefore, Calvert et al. concluded that a completely watertight closure was not essential for a good functional result and that arthrography may not be helpful in the investigation of a possible failure of repair.

We do not believe that arthrography is ideal for demonstrating the integrity of a repaired cuff. A leak may or may not mean that the reattachment of tendon to bone has failed. Also, it is difficult to determine the size of a recurrent defect with the use of this technique²¹. Finally, arthrography is an invasive procedure and is contraindicated if an equally accurate, less risky, and less expensive method is available.

We and others^{6,15} have previously reported on the accuracy of experienced sonographers in the evaluation of repairs of torn rotator cuffs. In a previous study¹⁵, we were able, with ultrasonography, to diagnose a second tear of the cuff accurately in twenty-six shoulders and to confirm the integrity of the cuff in ten of eleven shoulders for which operative proof of the tear was available. With ultrasonography, one is not able to determine whether a recurrent defect is due to inadequate healing of the repair, loss of the fixation that had been accomplished with sutures, or additional tearing of degenerated tissue of the cuff¹⁶. Thus, such

a tear may be more properly called secondary, rather than recurrent.

In the present series, we found that sixty-eight (65 per cent) of 105 repaired rotator cuffs had remained intact at an average of five years (range, two to eleven years) after the operation. This finding is consistent with the data of Pettersson and those of Lundberg, who each used radiographic and arthrographic methods to estimate that there was a secondary tear in one-third of the repaired cuffs in their series at the time of long-term follow-up. In our study, no patient in whom a partial-thickness tear had been repaired had a full-thickness tear at the time of the latest follow-up. In 80 per cent of the shoulders in which a full-thickness tear of the supraspinatus tendon had been repaired, the cuff was found to be intact at the latest follow-up. At an average of six years postoperatively, this was true of only 57 per cent of the cuffs in which the tear had involved the supraspinatus and infraspinatus tendons. Fewer than one-third of the cuffs in which the tear had involved all three major tendons were noted to be intact at an average of four years of follow-up. Therefore, it is evident that a secondary defect is more likely to develop in a rotator cuff in which a large tear was repaired. This may be a reflection of the age of the patient and the quality of the tissue, the effect of mobilization of the tendon on the viability of the tendon, or the fact that it is more difficult to implant healthy tendon securely in bone when there is a major deficiency in the cuff.

Ultrasonographic evaluation provided another advantage: it permitted inspection of the contralateral shoulder. Using ultrasonography, we found a very high prevalence (55 per cent) of bilateral lesions of the rotator cuff. This rate is higher than that recorded in previous reports^{20,22}.

Correlation of the Follow-up Type with the Functional Result

There was a significant correlation between the integ-

riety of the repaired rotator cuff at the latest follow-up and the function of the shoulder. The shoulders that did not have a full-thickness recurrent defect (follow-up type 0 or 1A) had a significantly better active range of motion, strength, and function in terms of the patient's ability to perform activities of daily living. The ability to use the extremity away from the body and over the head also correlated strongly with the integrity of the repaired rotator cuff.

The integrity of the cuff, as reflected by the follow-up type, also correlated significantly with the comfort and satisfaction of the patient. The patients who had an intact cuff were the most comfortable; 92 per cent of such shoulders were free of pain. Similarly, 96 per cent of the patients who had an intact cuff were satisfied. However, most (87 per cent) of the patients who had a recurrent defect were satisfied as well. In contrast to previous observations¹¹, our results suggest that it is difficult to detect recurrent defects of the cuff with clinical examination alone.

Correlation of Functional Result with Operative Type

Function, pain, and over-all satisfaction of the patient correlated much less well with operative type than with follow-up type. The ability to perform only two of thirteen activities of daily living was worse after repair of a large tear than after repair of a small tear. Therefore, our results

do not support the idea that repair of a small tear yields predictably less pain and better function than repairs of a larger tear^{9,23}. Furthermore, our results do not support the concept that the size of the tear that was repaired is the major determinant of the strength of abduction and external rotation at the time of follow-up^{8,10,11}.

In summary, the integrity of the rotator cuff at the time of follow-up, not the size of the tear at the time of repair, is the major determinant of the outcome of an operative repair of a tear of the rotator cuff. Repair of a secondary tear is likely to yield a result that is comparable with that of repair of a primary tear if, after both procedures, the cuff remains intact. Similarly, repair of a large tear will yield a result that is comparable with that of repair of a small tear if, again, the cuff remains intact after both operations. However, there is less of a chance that a cuff in which a large tear has been repaired will remain intact than that a cuff in which a small tear has been repaired will remain intact. In our series, the older patients tended to have larger tears and a higher prevalence of secondary defects. Our data suggest that the quality of the tissue of the cuff, its attachment to bone, and the potential for a durable repair deteriorate with age or disuse.

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