MAJOR RUPTURES OF THE ROTATOR CUFF

THE RESULTS OF SURGICAL REPAIR IN 89 PATIENTS

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Major ruptures of the rotator cuff were repaired in 89 patients over a six-year period, using an approach through the split deltoid muscle and the bed of the excised outer centimetre of the clavicle. Review of these patients showed that poor results were associated with larger cuff defects, with more pre-operative steroid injections and with pre-operative weakness of the deltoid muscle.

A randomised prospective study showed that repair followed by splinting in abduction gave no better results than repair followed by resting the arm at the side. Excision of the coraco-acromial ligament was associated with worse results than leaving its divided halves *in situ*. Follow-up showed that the results continued to improve for two years after operation; their quality was maintained in patients less than 60 years old, but in those over 60 there was deterioration with time.

Major rupture of the rotator cuff is an incapacitating event, the pathology and treatment of which remain controversial. The records of 89 patients having an operation for the condition were studied in order to clarify the pathology. The repair operation was varied randomly to provide a prospective trial of different methods of treatment.

Rupture of the rotator cuff was first recorded by Smith in 1834, and our knowledge was expanded by Codman 100 years later in his remarkable privately published book. Since then a series of investigators have clarified the nature of the lesion (Skinner 1937; Lindblom 1939; Cotton and Rideout 1964; Weiner and Macnab 1970; Neer 1972; Kessel and Watson 1977). It would appear that chronic degeneration occurs in the relatively ischaemic superior part of the cuff as a result of impingement on the deep surface of the acromion, the coraco-acromial ligament and the expanded degenerate acromioclavicular joint. Complaints of a painful arc of movement gradually become worse until the cuff ruptures. Weakness of shoulder movement, and especially of abduction, then overtakes pain as the main problem.

Local steroid injections are often used for the pain, since they have a good analgesic effect (Hollingworth, Ellis and Hattersley 1983). However, repeated injections have been reported to cause severe local destruction at other sites, and it would be surprising if such damage did not also occur in the shoulder (Sweetnam, Mason and Murray 1960; Bentley and Goodfellow 1969; Salter and Murray 1969; Ishikawa 1981). This study includes an assessment of the effect of previous steroid injections on the outcome of surgical repair.

Many papers record the results of cuff repair: most are in terms of the personal approaches and methods of the authors and often lack critical evaluation of the different techniques (Bosworth 1940; McLaughlin 1944; Debeyre, Patte and Elmelik 1965; Bush 1975; Neviaser, Neviaser and Neviaser 1978; Packer *et al.* 1983; Post, Silver and Singh 1983). The present paper analyses the significance of those factors likely to influence the results of repair.

These factors can be considered in two groups. First, those over which the surgeon has no control, such as local steroid injection before operation, the size and position of the cuff defect, and the degree of hypertrophic acromioclavicular degeneration; these three probable determinants of the result were recorded at the time of operation in the 89 patients who had various types of repair. Secondly, the factors over which the surgeon has some influence, such as pre-operative preparation, the strength of the deltoid muscle, the surgical approach, the type of repair and the postoperative management.

The rotator cuff stabilises the glenohumeral joint while the deltoid muscle abducts the humerus (Poppen and Walker 1978). Repair of the cuff cannot restore abduction if the deltoid muscle is weak. The result of repair was therefore related to the power of that muscle on the MRC scale, assessed just before operation.

Restoration of anatomical continuity at operation is often impossible. Faced with a retracted and shrunken remnant of rotator cuff the surgeon has a choice of four techniques: he may abduct the arm to bring the tuberosities to the retracted stump; he may attach the stump to the humeral head in the position it reaches *in situ*; he may bridge the defect with a graft or synthetic material; or he may advance the remnant by releasing the muscle belly from the scapula (Figs 1 to 4). In this prospective series random selection was made of either abduction with

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Diagrams to show the types of repair of the rotator cuff possible when shortening of the residual cuff makes anatomical restoration impossible. Figure 1—Repair to the tuberosities allowed by abduction and splinting. Figure 2—Repair to the head of the humerus with the arm at the side. Figure 3—Repair with a graft. Figure 4—Repair with advancement of the whole of the supraspinatus.

anatomical repair or repair to the head *in situ*. The other two options, graft bridging or advancement of the muscle, were considered to be less likely to restore the tone of the rotator cuff and therefore unlikely to restore a fulcrum for movement of the humerus.

The repaired cuff may impinge on the deep surface of the coraco-acromial arch and suffer rupture. Decompression of the repair by excision of the coraco-acromial ligament might therefore be considered helpful, so a randomised prospective trial of this was included in the series.

The patients in this series were followed up at yearly intervals for up to six years in order to assess the time taken to reach optimal recovery after operation and the durability of the repair. Neither of these features have previously been reported.

MATERIAL AND METHODS

The series reported includes 89 consecutive patients requiring operative repair of rotator cuff defects, all of which involved more than the width of a single major tendon of the cuff. Most patients were middle-aged or elderly and there were slightly more men than women (Table I).

A presumptive diagnosis of major rupture of the rotator cuff was made when chronic shoulder pain was associated with severe weakness of abduction in the presence of a functioning deltoid muscle. In 36 such patients plain radiographs showed severe acromioclavicular degeneration and marked upward migration of the humeral head (Fig. 5). In these patients a confident diagnosis was made without further investigation, and at operation all were found to have cuff ruptures of at least the width of one major tendon.

Arthrography. When physical signs and plain radiographs were not diagnostic, arthrography was performed. This revealed the defect in the cuff as an abnormal communication between the subdeltoid bursa and the shoulder joint. During the six years of the study 70 arthrograms were performed for this reason, of which six showed no defect. In 64 patients defects were seen and the shoulder was explored; in 11 the defects were less

than the width of a single major tendon and were not considered to be the chief cause of the symptoms. These patients are not included in the present study. The other 53 patients had major ruptures of the cuff and are included with the 36 who did not require arthrography.

The defect. The defect in the cuff was recorded by the position of its apparent origin and its size as a proportion of the whole cuff. Each of the three major tendons (subscapularis, supraspinatus and infraspinatus) was considered as three-tenths of the whole cuff while the long head of biceps tendon formed one-tenth. Thus rupture of the long head of the biceps alone would be termed a rupture of 1/10 of the cuff, rupture of the whole of the supraspinatus tendon would be recorded as involving 3/10 of the cuff and rupture of the whole cuff except the

Table I. Age and sex of 89 consecutive patients having an operation for major rupture of the rotator cuff

Age (years)	Men	Women	Total
20 39	7	2	9
40 59	31	22	53
60 80	16	11	27
	54	35	89

Fig. 5

Acromioclavicular joint degeneration in a patient with a major rupture of the rotator cuff. The bone on either side of the joint is enlarged by osteophytes and the head of the humerus has ascended to the acromion.

lower third of the subscapularis tendon would be a 9/10 rupture (Fig. 6).

Toughness of the remaining cuff. The toughness of the edge of the cuff was tested with a pull-out suture of strong ("0" gauge) monofilament nylon. This was passed perpendicularly through the torn cuff 1 cm from its margin, and 2 kg of traction was applied. If the suture cut out, the cuff remnant was deemed to be soft; if it held, the cuff tissue was recorded as tough.

Steroids. Patients were grouped into those who had had no local steroid injections, those who had had from one to four injections, and those who had had more than four.

Deltoid muscle. Power in this muscle was recorded on the MRC scale with the arm supported in a horizontal position by the examiner. Patients with less than Grade 3 were excluded from this study. Those patients with Grade 5 had early operation. Patients with Grade 3 or 4 were given a six-week course of strenuous exercises supervised by a physiotherapist. Deltoid power was then reassessed immediately before the operation for repair of the cuff.

Fig. 6

Recording the size and site of the defect: this diagram shows the imaginary subdivision of each of the main tendons into three parts (see text).

Operation. The approach used preserves the deltoid while giving wide access and allowing early rehabilitation. A sabre-cut incision is made in a skin cleavage line crossing the acromioclavicular joint. The lateral centimetre of the clavicle is excised and any bony protuberances removed from the deep surface of the acromion and the clavicular stump. The deltoid muscle is split downwards from its origin at the acromioclavicular joint and the coraco-acromial ligament divided. Retraction of the deltoid muscle and passive movement of the arm then allows inspection of the whole of the rotator cuff (Fig. 7). Its state is recorded as well as the position and size of the defect with the arm in the position of function—that is, in moderate flexion and medial rotation.

Repair. In 26 patients it was possible to stretch the retracted cuff remnant back over the head of the humerus and to fix it to its original insertion while the arm re-

Fig. 7

Diagram of the operative approach. The lateral centimetre of the clavicle has been excised, and the deltoid split and retracted. This exposes the coraco-acromial ligament and the underlying rotator cuff.

maintained at the side of the body. Horizontal mattress sutures of tough non-absorbable monofilament material were passed through the tuberosities and tied on the bony extra-articular surface (Fig. 8). The arm was then supported by a sling for five weeks.

In the other 63 patients the cuff remnant could not be pulled back over the humeral head. Alternate patients were treated by *in situ* fixation of the cuff remnant to the head without abduction of the arm, or by making anatomical fixation possible by shoulder abduction.

For *in situ* fixation the arm was left resting by the side. The edge of the cuff remnant was mobilised and then fixed by horizontal mattress sutures into the floor of a bony trench cut into the articular surface of the humeral head (Fig. 9). The arm was supported by a sling for five weeks.

An anatomical repair was made by pulling the cuff remnant as far as possible over the humeral head and

Fig. 8

Fig. 9

Diagram to show the techniques of repair using heavy mattress sutures. Figure 8—Anatomical repair to the tuberosity, made possible by abduction of the shoulder. Figure 9—Repair "*in situ*", to the head of the humerus, with the arm resting at the side.

Table II. Number of patients reviewed related to years after operation

	Years of follow-up						Total
	1	2	3	4	5	6	
Number reviewed	18	25	21	13	7	5	89
Number died	0	1	2	3	2	0	8

then abducting the arm to bring the tuberosities to the margin of the cuff. Fixation was by the same suture technique. The arm was held in the abducted position in a thoracobrachial cast for five weeks.

After release from sling or cast after five weeks, rehabilitation for both repairs was by gentle active and passive movement under the supervision of a physiotherapist until the clinical state was stable.

Ligament excision. In 36 of the patients the repaired area of the cuff impinged against the stumps of the divided coraco-acromial ligament. In alternate patients either the two parts of the divided ligament were completely removed or the ligament was left in its divided state.

Follow-up. All patients were reviewed annually for up to six years during the period of study. The number of operations increased each year throughout the study; thus five were followed for six years, while 18 had completed one year of follow-up. Eight patients died from diseases unrelated to their shoulder during the period of the study, but all of these had at least one year of follow-up and are included (Table II).

Shoulder score. A comprehensive score for shoulder comfort and function was decided at each follow-up. A perfect shoulder scored 100 points; a completely useless severely painful joint scored 0.

The patient's opinion was scored from 0 to 50, where 50 was complete satisfaction and 0 was total dissatisfaction.

The surgeon awarded a possible maximum of 50 points. Complete pain relief scored 20, moderate residual pain 10 and severe pain nil. Power of abduction was scored from a possible 20 points. The MRC grade was assessed with the arm abducted 45° and multiplied by four to give the score in points; for example, an MRC motor Grade 3 power obtains a score of 12. As an index of mobility, the passive range of abduction in the scapular plane at the glenohumeral joint was added to the range of glenohumeral rotation. A normal fully mobile joint would score 120 plus 180 = 300. This figure was then divided by 30 to give a score for passive range of movement. On this scale 300° would score 10 points and 150° score 5 points (Table III).

A score of over 75 points was considered to be good, 50 to 75 was fair, and less than 50 was poor.

RESULTS

Size and position of the defect. These were not related to any of the determining factors except acromioclavicular degeneration. In all 67 patients who had enlargement of

Table III. Shoulder score: the distribution of points (see text)

Patient's opinion	0 50
Surgeon's assessment	
Pain	0 20
Power of deltoid	0 20
Passive range of movement (abduction plus rotation)	0 10
Total	0 100
Normal shoulder = 100	

the joint with distortion of the underlying coraco-acromial ligament, the origin of the defect lay beneath this joint when the arm was placed in the position of function—that is, in moderate medial rotation, abduction and flexion. In 40 of these 67 the origin of the defect was at the centre of the supraspinatus tendon; in 11 the subscapularis tendon was the origin of the defect. In the other 16 cases the defect involved both supraspinatus and subscapularis tendons and was centred over the tendon of the long head of the biceps; in 10 of these 16 the biceps tendon had ruptured, but in 6 it was intact.

In the 22 patients in whom the acromioclavicular joint was not enlarged the origin of the defect was at the infraspinatus tendon in eight, the subscapularis tendon in nine and the supraspinatus tendon in five. The biceps tendon had ruptured in association with four of the lesions of the subscapularis tendon but with none of the supraspinatus or infraspinatus lesions.

The largest lesions were those centred over the supraspinatus and the biceps tendons. Of the 45 supraspinatus lesions, 40 involved 8/10 or more of the cuff; 11 of the 16 biceps-centred lesions showed rupture of at least 8/10 of the cuff. There were no complete ruptures, the so-called "bald-heads"; it was always possible to demonstrate some intact infraspinatus or subscapularis tendon at the margins of the defect.

Fewer larger defects originated on subscapularis and infraspinatus. Of 20 lesions begun on the subscapularis tendon nine were 8/10 or more and six were 4/10 or less. Of the eight lesions centred on the infraspinatus tendon only three involved 5/10; the remaining five were smaller (Table IV). The size of the defect had a marked effect on the outcome. Of the 60 patients with defects of

Table IV. Relation between the position of the defect and its size expressed as tenths of the total cuff (see Fig. 6)

Position of origin	Size of defect in tenths of cuff			Total number
	8 9	5 7	3 4	
Supraspinatus	40	4	1	45
Long head of biceps	11	3	2	16
Subscapularis	9	5	6	20
Infraspinatus	0	3	5	8
	60	15	14	89

8 9/10 of the cuff, 37 had good results (62%) and 11 had poor results. Of 15 patients with 5 7/10 defects, 13 had good results (87%); and of 14 with 3 4/10 defects, 12 had good results (86%) and two had fair results (Table V). The position and the size of the defect had a linked influence on the result since the larger defects, centred over the supraspinatus tendon, gave poorer results than the smaller defects near the front or the back of the cuff (see Tables IV and V).

Steroid injections before operation. Three groups of patients were compared. All seven patients who had had no local steroids had tough residual cuff tissue; five had good results (71%), two had fair results and there were no poor results. Of the 62 patients who had had from one to four steroid injections, 49 had tough residual cuff tissue and 13 had soft tissue; there were 48 good results (77%), 10 fair and four poor results. Of the 20 patients who had had more than four steroid injections, 17 had soft residual cuff tissue; there were nine good results (45%), three fair and eight poor results (Table VI). The state of the cuff had considerable prognostic significance. Of 30 patients with soft cuffs, 17 (57%) had good results; of 59 patients with tough cuffs, 45 (76%) had good results (Table VII).

Power of the deltoid muscle. Deltoid power before operation was an important factor in the outcome of treatment. Of the 62 patients with normal (MRC Grade 5) power, 55 (89%) had good results. In 12 of these the power of the muscle had improved from Grade 4 as a result of pre-operative exercises. Of the 27 patients with power of Grade 3 or 4, only seven (26%) had good results (Table VIII).

Postoperative position of the shoulder. There seemed to be no advantage in splinting the arm in abduction for five weeks after operation. Thus 21 of 31 patients (68%) who were splinted had good results as against 20 of 32 (63%) comparable patients who had repair *in situ*.

There were, however, eight poor results in the splinted group and only two in the other group (Table IX). This imbalance between fair and poor results in these two groups was striking: the poor results in the splinted group had very stiff shoulders, with winged scapulae, but pain was similar in both groups.

Ligament excision. Excision of both halves of the coraco-acromial ligament appeared to be harmful. Of the 18 patients who had "decompression" of the repaired cuff by this means, 11 (61%) had poor results. A comparable group of 18 who had no decompression had five (28%) poor results and 10 good results (Table X).

Follow-up. Review was at from one to six years. The results after one year were not as good as those assessed later, but at two years maximal improvement appeared to have been reached (Table XI). Beyond six years gradual deterioration was possible, but there were too few long-term cases to detect any factors affecting the durability of the repair apart from the age of the patient. Older patients did not maintain their good results as well

Table V. Relation between the size of the defect in tenths of the cuff and the results of operation

Size of defect	Result			Total
	Good	Fair	Poor	
8 9 10	37	12	11	60
5 7 10	13	1	1	15
3 4 10	12	2	0	14
	62	15	12	89

as younger patients. Those over 60 years of age had 80% good results after two years but among those reviewed four, five and six years postoperatively there were only 27% of good results. Patients aged under 60 had less deterioration with time (Table XII).

DISCUSSION

The size and position of the defect. It has been clearly shown that the larger the defect seen in the rotator cuff at operation the poorer the result. This is probably due to a combination of factors including increased tension in the suture line and the severity of the soft-tissue fibrosis. These facts allow the surgeon to make an accurate prognosis and it seems advisable therefore to assess the size of the defect before embarking on surgical repair. Arthrography or arthroscopy both allow such an assessment, and the use of one or the other is strongly advised before a decision is made to operate.

It is also clear that most ruptures of the rotator cuff occur where the deep surface of the enlarged acromioclavicular joint impinges on the cuff when the shoulder is in the position of function. The operative approach described removes the offending enlarged outer end of the clavicle and the nearby osteophytes. Approaches which preserve this joint may lead to continued impingement and further rupture. An additional benefit of the recommended approach is that it preserves deltoid function while allowing adequate access for any repair.

Pre-operative local steroid injection. This study has shown a link between the number of steroid injections and the outcome of treatment: the more steroid the worse the result. More injections were associated with a softer residual cuff, and it seems reasonable to assume that the poor results were due to giving way of this soft tissue. It is not clear whether the local steroids caused the softening; it is possible that more steroid injections were given to patients with softer cuffs because they had more severe symptoms. However, since four or more local steroid injections militate against a good result, it seems advisable to make any decision about surgical repair before four injections have been given. Should operation not be advisable, then local steroids may be used for their analgesic effect.

Deltoid power. Results are clearly poor in patients with

Table VI. Relation between the number of local steroid injections, the state of the cuff remnant and the result of operation

Number of steroid injections	State of cuff		Result of operation			
	Soft	Tough	Good	Fair	Poor	Total
5 or more	17	3	9	3	8	20
1 to 4	13	49	48	10	4	62
None	0	7	5	2	0	7
	30	59	62	15	12	89

Table VII. Relation between the state of the remaining rotator cuff (its resistance to a suture pulling out) and the result of operation

State of cuff	Result of operation			
	Good	Fair	Poor	Total
Soft	17	3	10	30
Tough	45	12	2	59
	62	15	12	89

Table VIII. Relation between the power of the deltoid muscle before operation and the result of treatment

Pre-operative power of deltoid*	Result of operation			
	Good	Fair	Poor	Total
Grade 5	55	7	0	62
Grade 3 to 4	7	8	12	27
	62	15	12	89

* MRC scale.

Table IX. Results related to the position of the arm after operation

Postoperative management	Results			
	Good	Fair	Poor	Total
Splinted in abduction	21	2	8	31
No splinting	20	10	2	32
	41	12	10	63

Table X. Results related to excision of the coraco-acromial ligament

Coraco-acromial ligament after division	Result of operation			
	Good	Fair	Poor	Total
Excised	3	4	11	18
Not excised	10	3	5	18
	13	7	16	36

weak deltoid muscles. Every effort should therefore be made to strengthen this muscle before operation. It is seriously doubtful whether repair should be advised in patients whose deltoid power is less than Grade 4.

Table XI. Results related to number of years follow-up

Result	Follow-up in years						Total
	1	2	3	4	5	6	
Good	10	20	18	7	4	3	62
Fair	5	3	2	3	1	1	15
Poor	3	2	1	3	2	1	12
	18	25	21	13	7	5	89

Postoperative splinting. Immobilisation in abduction gives no clear advantage over resting the arm at the side. After five weeks, splinted shoulders are stiff with winging of the scapula on movement.

Ligament excision to decompress the cuff. There seems no doubt that decompression of the cuff by excision of the coraco-acromial ligament militates against a good result. This may be because the ligament supports the repaired cuff and prevents passive stretching early after operation; removal may allow the strong deltoid muscle to pull the humeral head proximally, causing stretching and damaging the repair.

Prognosis. Patients under 60 years of age at the time of operation can safely be told that the result after two years is likely to last; repair in older patients seems much less durable. The reason for this is not clear but since postoperative function is so dependent on good deltoid power, ageing in this muscle may be responsible for late deterioration in elderly patients.

Most of the factors responsible for a poor outcome after cuff repair appear to occur in the same patients. Thus large defects appear in patients with soft residual cuff material who have had many local steroid injections and who are past the age of 60. These factors are unfortunately beyond the influence of the surgeon. However, he can improve other factors; a powerful deltoid muscle can be achieved by exercises, which is reflected in improved results of repair. It has also been shown that splinting the shoulder in abduction after cuff repair and excision of the halves of the divided coraco-acromial ligament are harmful.

Table XII. Results related to length of follow-up and to the age of the patient

Age group	Result	At 2 years	At 4, 5 and 6 years
Patients under 60	Good	12	11
	Fair	2	2
	Poor	1	1
Patients over 60	Good	8	3
	Fair	1	3
	Poor	1	5

Other studies. Since Codman's work of 1934 several large studies have appeared in the English literature. McLaughlin and Asherman (1951) describe 100 cases of operative repair of cuff lesions. There were 18 "massive avulsions" and 66 "complete" tears. The rest were incomplete (partial thickness) tears. The massive avulsions and the complete tears were probably comparable with those of the present study. Of these 84 patients there were 48 good results (57%). The technique of repair was similar to the repair *in situ* in the present study, with the addition of an acromionectomy. There was no information about any of the determinants of the outcome discussed in the present paper.

Weiner and Macnab (1970) studied 70 cases, comprising 7 small, 11 medium, 34 large and 18 massive tears. The medium, large and massive tears are probably comparable with the present series. There were 38 good results overall; excluding the small tears, 60% good results were obtained. Wolfgang (1978), using a technique very similar to that reported here, obtained 34 good or excellent results (74%) from a total of 46 cases.

Packer *et al.* (1983) described 63 cases. A variety of techniques was used, most with acromionotomy and some form of subacromial decompression. They reported 40 good results (63%); these were significantly better in patients who had decompression of the repair by anterior acromioplasty, anterior acromionectomy, division of the coraco-acromial ligament or excision of the outer end of the clavicle. None of the other possible determinants of the outcome was reported. Since all the patients in the present series had decompression by the last two of the methods listed by Packer *et al.* it was not possible to compare this in the two series. The additional "decompression" in the present series involved excision and not just division of the coraco-acromial ligament.

Post, Silver and Singh (1983) gave the results of repair in 55 cases. Pain and dysfunction were assessed separately but the results were broadly similar to those of the other studies. Pre-operative deltoid muscle power was determined and they found little correlation between this and the result. The other possible factors determining the outcome were not assessed.

CONCLUSIONS

This study has shown that after major rotator cuff rupture:

- the larger the defect the poorer the result;
- pre-operative local steroid injections in excess of four injections are associated with a poor result;
- deltoid muscle power of less than Grade 4 before operation is associated with a poor outcome;
- postoperative splintage in abduction does not improve the long-term results;

excision of the coraco-acromial ligament at the time of repair is harmful;

the quality of the result improves for two years after the operation;

the result is maintained except in patients over 60, whose shoulders gradually deteriorate with the passage of time.

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