Loss of the deltoid after shoulder operations: An operative disaster

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A series of 36 patients who had a postoperative loss of the anterior or anterior lateral deltoid muscle after shoulder operations (i.e., acromioplasties, anterior shoulder reconstructions, or arthroplasty procedures) was referred to the senior author. Three patients lost the function of their deltoid after an injury to the axillary nerve, and 33 patients lost deltoid function after loss of the origin of the deltoid from the clavicle and acromion. All patients were significantly disabled. All patients were dissatisfied with the result of the previous operation, and eight patients experienced painful anterior or anterior/superior dislocation of the glenohumeral joint. Treatment was nonspecific and supportive. The authors conclude that loss of anterior deltoid function secondary to denervation or detachment results in irrevocable pain and impairment of function. Careful attention to the surgical technique of deltoid reattachment and protection of the axillary nerve are essential to the prevention of dire consequences to shoulder function. (J SHOULDER ELBOW SURG 1994;3:243-53)

The deltoid, especially the anterior deltoid, is a most important, unique, and irreplaceable muscle of the shoulder. In the normal shoulder the deltoid provides 50% of the power for elevation of the arm in the scapular plane.[5, 20] However, patients with massive rotator cuff defects can exhibit full overhead elevation of the glenohumeral joint, especially after a rehabilitation program.* Injury to the deltoid is poorly tolerated; even injury confined to the anterior deltoid alone may preclude any overhead activity.†

With the introduction of vaccine, poliomyelitis as a cause of deltoid loss is rarely seen. Deltoid loss is now most commonly seen as a result of iatrogenic injury to the deltoid during shoulder operations, motor vehicle plexus injuries, and gunshot wounds.[5] These iatrogenic injuries will serve as the focus of this report.

*References 6, 9, 21, 25, 26, 29, 34, 40-42.

†References 2, 3, 5, 10-13, 21, 30, 32, 34.

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MATERIAL AND METHODS

Thirty-six patients with deltoid deficiencies were referred to the senior author (C.A.R.) for evaluation after having undergone a previous operative shoulder procedure. The average age of the patients was 55 years (range 25 to 77 years). Fourteen women and 22 men were studied. Twenty-three patients presented with right shoulder complaints, and 13 patients presented with left shoulder complaints (Table I).

The patients had undergone an average of 2.1 operative procedures (range one to four) before the referral. Fourteen patients had undergone one previous procedure, nine patients had undergone two, seven patients had undergone three, and six patients had undergone four previous surgical procedures. Previous operative procedures are listed in Table II. The last operative procedure had been performed for the group an average of 28 months before being evaluated (range 3 to 162 months).

The location of the previous incision was determined for all patients. Twenty patients had

Table I Patient data

Patient	Age (yr), sex	Previous operation	Incision type	Extent of deltoid split/detachment	Deltoid repair
1	64, F	Hemiarthroplasty	Deltopectoral	Anterior detachment	Deltotrapezial fascia
2	41, F	Bristow	Axillary	Anterior detachment	Deltotrapezial fascia
3	75, F	Revision total shoulder	Deltopectoral	Anterior detachment	Deltotrapezial fascia
4	77, F	Total shoulder	Deltopectoral	None	None
5	56, M	Hemiarthroplasty	Deltopectoral	None	None
6	55, M	Inferior acromioplasty	Deltoid splitting	Split of 3 cm	Deltotrapezial fascia
7	76, M	Inferior acromioplasty	Deltoid splitting	Deltoid split 4 cm	Deltotrapezial fascia
8	41, M	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 5 cm	Deltotrapezial fascia
9	64, F	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 4 cm	Deltotrapezial fascia
10	64, M	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 5 cm	Deltotrapezial fascia
11	34, M	Inferior acromioplasty and distal clavicle excision	Deltoid splitting	Deltoid split 3 cm	Deltotrapezial fascia
12	68, M	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 3 cm	Deltotrapezial fascia
13	45, M	Inferior acromioplasty and biceps tenodesis	Deltoid splitting	Deltoid split 2 cm	Deltotrapezial fascia
14	71, F	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 5 cm	Deltotrapezial fascia
15	40, M	Revision total shoulder	Deltopectoral	None	None
16	32, F	Revision total shoulder	Deltopectoral	Detachment of anterior deltoid	Deltotrapezial fascia
17	64, M	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 4 cm	Deltotrapezial fascia
18	63, M	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 3 cm	Deltotrapezial fascia
19	77, F	Hemiarthroplasty	Deltopectoral	Detachment of anterior deltoid	Deltotrapezial fascia
20	77, M	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 4 cm	Deltotrapezial fascia
21	25, M	Magnuson-Stack	Axillary	Detachment of anterior deltoid	Deltotrapezial fascia
22	60, M	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 4 cm	Deltotrapezial fascia
23	71, M	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 3 cm	Deltotrapezial fascia
24	68, F	Total shoulder	Deltopectoral	Detachment of anterior deltoid	Deltotrapezial fascia

M, Male; *F*, female; *RTC*, rotator cuff.
*Degrees of forward elevation, external rotation, and internal rotation to the spinous process.
†Functional result; see text and Table III.

Table I Cont'd

Location of deltoid loss	Cause of deltoid loss	Coexisting shoulder problems	Range of motion*	Pain	Activities of daily living†
Anterior	Failure of repair	None	20/80/L1	Yes	Poor
Anterior	Failure of repair	Multidirectional instability	140/0/T8	Yes	Good
Anterior	Failure of repair	None	30/15/L5	Yes	Poor
Anterior, lateral, and posterior	Denervation	None	0/30/lateral hip	No	Poor
Anterior, lateral, and posterior	Denervation	None	0/45/lateral hip	Yes	Poor
Anterior	Failure of repair	Rotator cuff insufficiency	35/15/L4	Yes	Poor
Anterior, lateral, and posterior	Denervation	Rotator cuff insufficiency	0/10/L5	Yes	Poor
Anterior and lateral	Failure of repair	None	60/20//L1	Yes	Poor
Anterior	Failure of repair	Rotator cuff insufficiency	30/30/T8	No	Poor
Anterior	Failure of repair	Rotator cuff insufficiency	15/15/L5	No	Poor
Lateral	Failure of repair	None	140/40/T7	No	Good
Anterior, lateral	Failure of repair	None	40/15/T12	No	Poor
Anterior	Failure of repair	Rotator cuff insufficiency	30/75/T12	Yes	Poor
Anterior	Failure of repair	None	70/80/Sacrum	Yes	Fair
Anterior	Failure of repair	None	75/25/L1	Yes	Poor
Anterior and lateral	Failure of repair	None	15/60/T10	Yes	Poor
Anterior	Failure of repair	Rotator cuff insufficiency	15/45/Lateral hip	Yes	Poor
Anterior	Failure of repair	Rotator cuff insufficiency	65/25/lateral hip	Yes	Fair
Anterior	Failure of repair	None	75/15/lateral hip	Yes	Fair
Anterior and lateral	Failure of repair	Rotator cuff insufficiency	10/25/T12	Yes	Poor
Anterior	Failure of repair	None	155/30/L1	No	Good
Anterior and lateral	Failure of repair	None	20/25/L1	Yes	Poor
Anterior and lateral	Failure of repair	None	10/0/L5	No	Poor
Anterior	Failure of repair	None	45/45/L1	Yes	Poor

Cont'd

Table I Patient data (Cont'd)

Patient	Age (yr), sex	Previous operation	Incision type	Extent of deltoid split/detachment	Deltoid repair
25	48, M	Total shoulder	Deltopectoral	Detachment of anterior deltoid	Deltotrapezial fascia
26	35, M	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 4 cm	Deltotrapezial fascia
27	73, F	Hemiarthoplasty	Deltopectoral	Detachment of anterior deltoid	Deltotrapezial fascia
28	66, F	Hemiarthroplasty	Deltopectoral	Detachment of anterior deltoid	Deltotrapezial fascia
29	52, M	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 4 cm	Deltotrapezial fascia
30	31, M	Open reduction and internal fixation	Deltopectoral	Detachment of anterior deltoid	Deltotrapezial fascia
31	61, M	Total shoulder	Deltopectoral	Detachment of anterior deltoid	Deltotrapezial fascia
32	25, M	Inferior acromioplasty and biceps tenodesis	Deltoid splitting	Deltoid split 5 cm	Deltotrapezial fascia
33	56, M	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 3 cm	Deltotrapezial fascia
34	50, F	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 4 cm	Deltotrapezial fascia
35	69, F	Inferior acromioplasty and RTC repair	Deltoid splitting	Deltoid split 4 cm	Deltotrapezial fascia
36	26, M	Bristow	Axillary	Detachment of anterior deltoid	Deltotrapezial fascia

Table II Previous operative procedures

Type of procedure	Total = 36
Acromioplasty/cuff repair	15
Hemiarthroplasty	5
Acromioplasty	2
Total shoulder arthroplasty	4
Revision of total shoulder arthroplasty	3
Internal fixation of proximal humerus fracture	1
Bristow procedure	2
Magnuson-Stack procedure	1
Acromioplasty and biceps tenodesis	2
Acromioplasty and distal clavicle excision	1

an approach through an anterosuperior incision (deltoid-splitting) along the lateral border of the acromion. In 13 patients the incision was a long deltopectoral approach. Three patients had an anterior axillary incision. In 20 patients a distal split of the deltoid was performed (Table I). In 13 patients a portion of the deltoid was released during the initial operative procedure. In three patients there was neither splitting nor release of any of the deltoid fibers.

The location of the deltoid loss was distributed as follows: 25 patients had loss of the anterior deltoid, seven patients had loss of the anterior and lateral deltoid, three patients had loss of the anterior, lateral, and posterior deltoid, and one patient had loss of the lateral deltoid. The etiology of the deltoid loss was determined to be detachment of the deltoid in 33 patients. Three patients suffered complete denervation of the deltoid. Of the three patients who had denervation of the deltoid, one patient had undergone a hemiarthroplasty and another a total shoulder arthroplasty, both through a deltopectoral incision. The remaining patient suffered denervation of the deltoid through a deltoid-splitting incision for acromioplasty (Table I). The remaining 32 patients had detachment of the deltoid after undergoing the procedures through the incisions listed in Table I.

In addition to loss of the deltoid, 15 (42%) patients had coexisting shoulder problems that were believed to be symptomatic. Twelve patients demonstrated continued signs of an insufficient and degenerative rotator cuff, two patients had multidirectional instability of their shoulder, and one patient had continued anterior instability after an initial traumatic event.

Table I Cont'd

Location of deltoid loss	Cause of deltoid loss	Coexisting shoulder problems	Range of motion*	Pain	Activities of daily living†
Anterior	Failure of repair	None	75/25/T11	No	Fair
Anterior	Failure of repair	Instability	60/5/L4	Yes	Poor
Anterior	Failure of repair	None	10/25/L5	Yes	Poor
Anterior	Failure of repair	None	60/30/L1	No	Fair
Anterior and lateral	Failure of repair	Rotator cuff insufficiency	35/50/T10	Yes	Poor
Anterior	Failure of repair	None	80/0/L5	Yes	Fair
Anterior	Failure of repair	None	35/35/L5	Yes	Poor
Anterior	Failure of repair	None	125/35/T12	No	Good
Anterior	Failure of repair	Rotator cuff insufficiency	25/5/Lateral hip	Yes	Poor
Anterior	Failure of repair	Rotator cuff insufficiency	30/0/Lateral hip	No	Poor
Anterior	Failure of repair	Rotator cuff insufficiency	30/65/Lateral hip	No	Poor
Anterior	Failure of repair	Multidirectional instability	170/40/T12	No	Good

Function of the involved shoulder was determined for various activities of daily living. All patients were questioned as to their ability to perform 15 tasks (Table III). A score of 15 was considered excellent, 13 to 14 was good, 10 to 12 was rated as fair, and below nine as poor.

RESULTS

Range of motion was measured for all patients. Forward elevation averaged 52° (range 0° to 170°, Figure 1). External rotation measured 30° (range −10° to 80°), and mean internal rotation was to the spinous process of the fourth lumbar vertebrae (range lateral hip to spinous process of the seventh thoracic vertebrae). Eight patients had anterior subluxation of the glenohumeral joint with forward elevation (Figure 2).

Twenty-two (60%) of the 36 patients had continued pain in the affected shoulder. Of the 21 patients with no coexisting shoulder problems, 13 had pain, whereas seven reported no pain. Seven of the patients with rotator cuff defects had pain, whereas five reported no pain. One patient with multidirectional instability complained of pain at the last examination, whereas one did not. The only patient with ongoing anterior instability complained of pain.

Table III Activities of daily living

1. Button blouse or shirt
2. Put arm into coat sleeve
3. Place hand behind head
4. Drink from glass or mug
5. Lift 10 pounds to shoulder height
6. Lift 10 pounds above shoulder height
7. Comb and brush hair
8. Brush teeth
9. Apply deodorant to opposite side
10. Carry a 10-pound suitcase
11. Carry a 25-pound suitcase
12. Carry a 50-pound suitcase
13. Throw underhand 10 yards
14. Throw overhand 30 yards
15. Throw overhand greater than 30 yards

Function for the 36 patients was determined by their ability to accomplish 15 tasks of daily living. No patient scored an excellent result. In five patients the result was rated as good, in six patients the result was rated as fair, and in 25 patients the result was rated as poor. The distribution of functional results with regard to coexisting problems revealed that the result of three of the 21 patients with no coexisting shoulder problems was rated as good, the result of

Figure 1 Patient with detachment of right anterior deltoid after acromioplasty and rotator cuff repair. **A,** Maximal forward elevation. **B,** Location of incision.

five as fair, and the result of 13 as poor. Of the 12 patients with symptomatic degenerative rotator cuff defects, 11 patients had a poor result, whereas only one result was rated as fair. The results of two patients with multidirectional instability were rated as good.

The distribution of functional results with regard to corresponding loss of the deltoid revealed one good result in the patient with an isolated lateral deltoid loss. All three patients with loss of the anterior, lateral, and posterior deltoid were rated as poor. Similarly, all seven of the patients with loss of the anterior and lateral deltoid were rated as poor. Of the 25 patients with loss of the anterior deltoid alone, the results of four patients were rated as good, six as fair, and 15 as poor. The average age of the patients with a rating of good was 30 years, as compared with the remainder of the group who had an average age of 60 years ($p < 0.01$). Only three (8.4%) patients of the 36 thought the function of the shoulder was satisfactory. All patients (100%) were dissatisfied with the result of the previous surgery.

DISCUSSION

The deltoid arises from the anterior and superior surface of the lateral third of the clavicle, from the lateral margin and adjoining upper surface of the acromion, and from the crest of the spine of the scapula. The deltoid is multipennate; the middle part of the muscle receives four or five tendons that descend from the acromion. The clavicular and scapular parts of the muscle converge to be inserted, together with the acromial part, into the deltoid tuberosity of the humerus.[15] The deltoid is innervated by the axillary nerve. The axillary nerve arises from the fifth and sixth cervical nerves and is formed from the terminal branch of the posterior cord of the brachial plexus. It crosses from medial to lateral along the anterior surface of the subscapularis muscle. At the inferior border of the subscapularis the nerve travels posteriorly under the inferior capsule of the glenohumeral joint. In many instances the axillary nerve gives off two branches that supply the inferior aspect of the capsule of the shoulder joint. At this point the axillary nerve joins with the posterior humeral circumflex artery, and together they exit

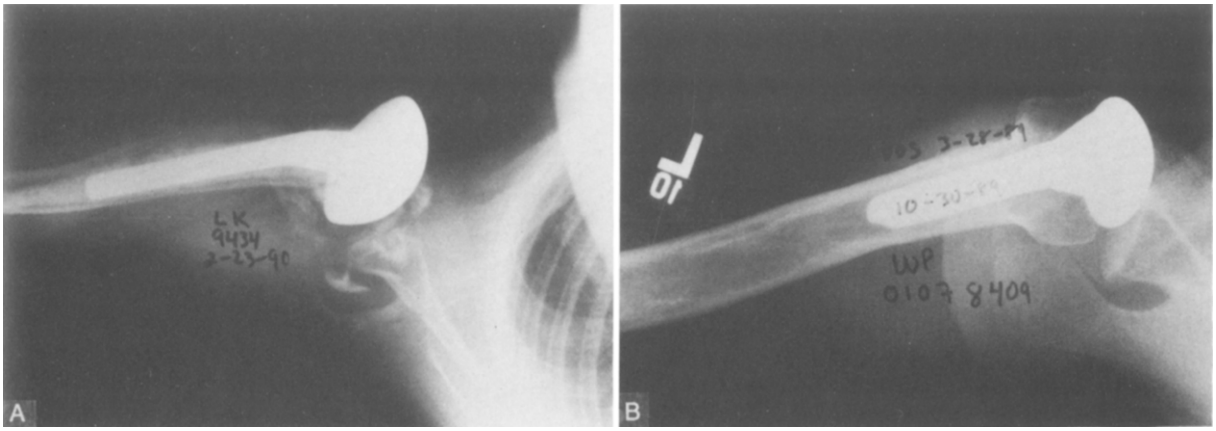

Figure 2 Axillary lateral radiographs. **A,** Patient with anterior detachment of deltoid and anterior subluxation with forward elevation after total shoulder arthroplasty. **B,** Patient with anterior detachment of deltoid and anterior subluxation with forward elevation after hemiarthroplasty.

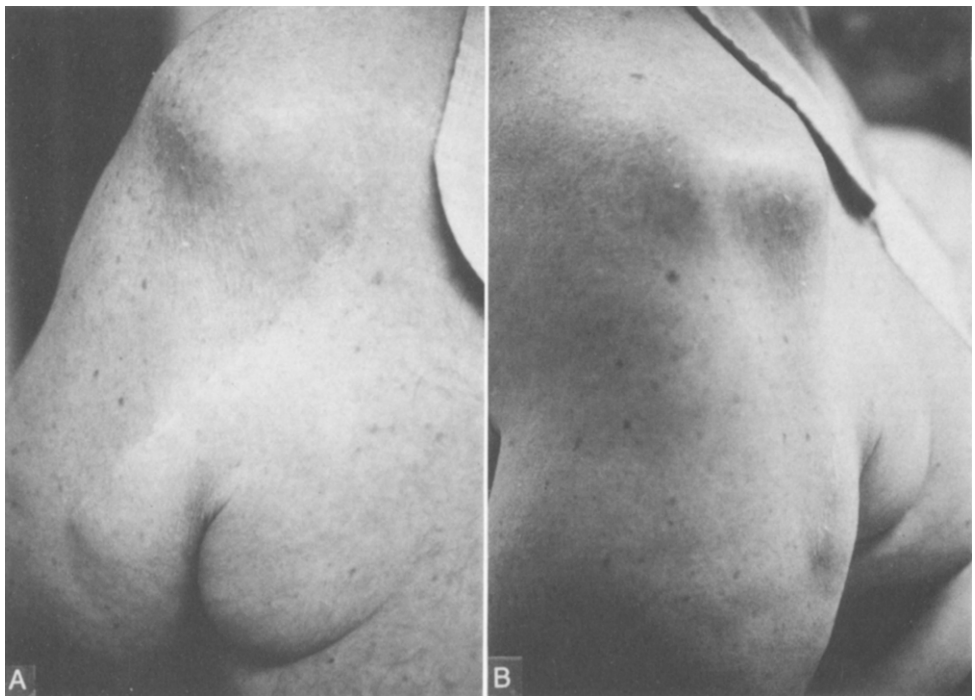

Figure 3 Appearance of shoulder after denervation of entire deltoid. Hemiarthroplasty was performed through extended anterior deltopectoral approach.

through the quadrangular space, where the axillary nerve splits into two major trunks. The posterior trunk gives off branches to the teres minor and posterior deltoid and terminates as the superior lateral cutaneous nerve of the arm. The anterior trunk passes anteriorly around the humerus and lies approximately 5 cm distal to the lateral border of the acromion. The nerve lies on the deep surface of the deltoid and supplies the lateral deltoid and then the anterior deltoid.[1, 10, 24]

Most anterior surgical approaches to the shoulder are performed either through a limited deltoid muscle split or through the deltopectoral interval.* The relationship of the axillary nerve to these approaches has been described by pre-

*References 1, 5, 14, 21, 25, 27-29, 31, 38.

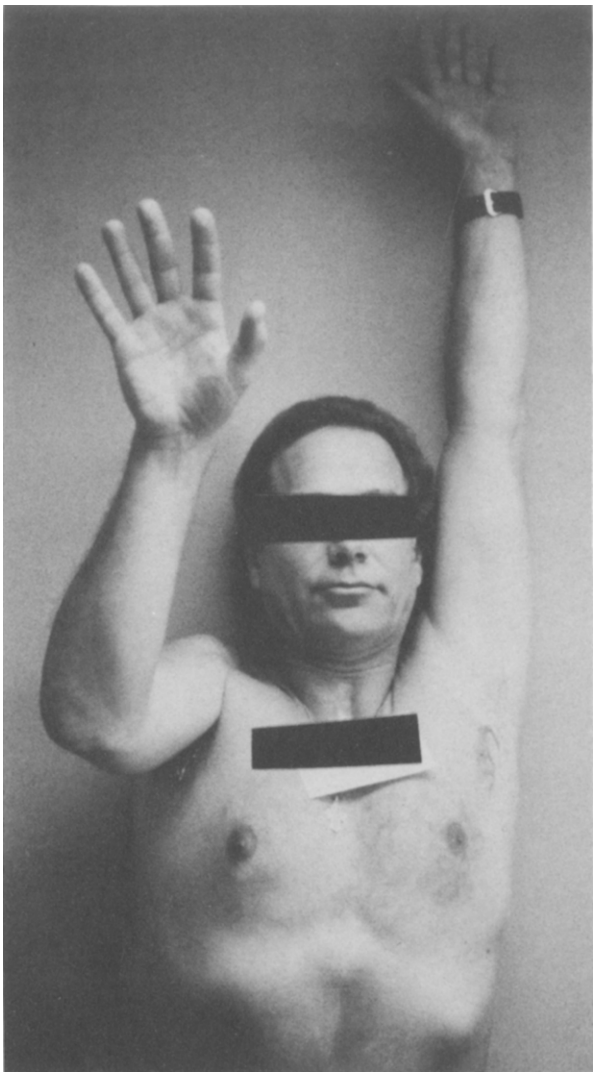

Figure 4 Patient with loss of anterior deltoid after surgical approach with anterior approach of Henry. Maximum active forward elevation.

vious authors.* Protection of the axillary nerve during a deltoid-splitting approach has generally consisted of limiting the incision to "no more than 5 cm" below the acromion.[10, 27] Similarly, the admonishment for protection of the axillary nerve during anterior shoulder approaches has been to place the arm in adduction and external rotation, to place the nerve farther from the operative field.[7, 31]

Injury to the axillary nerve. Laceration of the axillary nerve deinnervates the deltoid muscle and in this report was responsible for

*References 1, 7, 8, 10, 21, 25, 27, 29, 38.

Figure 5 Deltoid is repaired to bone *and* into deltotrapezial fascia, with heavy nonabsorbable, number 2 suture to ensure a reliable reattachment.

deltoid loss in three patients (Figure 3). The function of all three patients was rated as poor. The operative approach in two of these patients was deltopectoral and in the third was deltoid-splitting.[27, 29] Burkhead et al.[10] have described in detail the tremendous variation, from specimen to specimen, in the course and position of the axillary nerve. They report that previously described "safe zones" for all shoulders are significantly smaller than previously described. For this reason the authors advocate locating the axillary nerve during arthroplasty and reconstructive procedures. The volar surface of the index finger is slid along the anterior surface of the subscapularis muscle and then rotated anteriorly to hook the axillary nerve.[38] In cases of dense scarring and adhesions, a periosteal elevator may be used along the anterior surface of the subscapularis to identify the axillary nerve. A retractor may then be positioned to protect the nerve during capsular release.[38]

Because shoulder function requires elevation in the scapular plane, injury to the axillary nerve is a catastrophic injury. In 1935 Haas[16] advo-

cated transfer of the trapezius extended by a fascial graft for deltoid muscle paralysis. The procedure is accompanied by a long period of protection in an abduction brace and muscle training for more than 1 year. It was complicated by partial or complete failure of the trapezial transfer in a significant number of cases. Harmon[17] described anterior transplantation of the posterior deltoid in these cases, and Itoh[22] advocated transfer of the latissimus dorsi as an inverted pedicle graft. Although many other procedures have also been devised for treatment of this injury,* the results have been unpredictable.[11, 29, 30] Further, the transfers described to treat this condition have typically functioned as a tenodesis, have stretched with time, or do not have an effective range of motor fiber contractability.[5]

Loss of origin of the deltoid. More common and problematic has been loss of deltoid as a result of detachment from the acromion and clavicle after shoulder procedures. The three parts of the deltoid muscle, anterior, lateral, and posterior, must be considered separately, so far as actions are concerned. The lateral deltoid is a powerful abductor of the arm, but its line of pull is such that when acting alone it abducts the arm in the plane of the scapula. The posterior part of the deltoid extends the arm and rotates it laterally. Weakness of the posterior deltoid is less problematic, because the latissimus dorsi is a strong synergistic muscle.[12] The anterior deltoid flexes the arm and rotates it medially. No other effective muscle compensates for loss of this powerful shoulder flexor.[10]

Twenty-two of the 33 patients who suffered loss of the deltoid secondary to detachment of the anterior or anterior and lateral deltoid had shoulder function rated as poor. Only five patients in this group obtained a shoulder function rating of good, and these patients were considerably younger than the remainder of the patients studied. These five patients were further differentiated by possessing no coexisting shoulder problems in three, and multidirectional instability in the remaining two. Patients with more extensive loss of the deltoid (i.e., anterior and lateral) or coexisting shoulder problems appeared more likely to have a poor outcome (Figure 4).

*References 2, 3, 5, 11, 18, 19, 23, 29, 30, 33, 39.

In reviewing the results of previous series of rotator cuff procedures,[9, 29, 30, 34, 42] it becomes clear that a consistent subset of patients in these reports is reported as having poor results. Closer scrutiny of the data reveals that an equal number of patients is usually reported in the complications section of the reports as having detachment of the deltoid origin. Other authors[4, 13, 32] have reported poor results in patients undergoing revision rotator cuff surgery who have also had a detached or retracted deltoid. Indeed, in the senior author's[9] report of acromioplasty and rotator cuff debridement for massive, irreparable rotator cuff defects, three patients were reported as having a poor result. All three patients had had previous surgery, and all were noted, before surgery, to have lost the origin of their anterior deltoid.

Surgical treatment of deltoid avulsion has seldom been successful. Neer[30] described 30 patients who had previously had removal of 80% of the acromion with resultant adhesions of the deltoid to the rotator cuff, deltoid contracture, and loss of the acromial fulcrum. Surgical correction in 20 yielded generally poor outcomes. It is therefore imperative that surgical reconstruction does not jeopardize the deltoid.

The operative procedures for treating disease of the rotator cuff and acromion are similar in placing the deltoid origin at risk. In the approach to the shoulder as described by Neer,[27] he recommends placing a suture at the inferior aspect of the deltoid split to prevent continued splitting and potential injury to the axillary nerve. Furthermore, Neer recommends that the deltoid be repaired to the deltotrapezial fascia at the conclusion of the procedure. We are concerned that repair of the heavy deltoid muscle only to the deltotrapezius fascia is insufficient and may be responsible for detachment of the anterior deltoid and subsequent shoulder weakness. We believe that it is important to securely repair the deltoid back to bone with heavy number 2 nonabsorbable suture at the conclusion of the procedure (Figure 5).[9, 35, 36, 37] A secure repair of the deltoid to bone enables the surgeon to initiate range of motion of the shoulder immediately after the operation, and the authors have experienced no case of detachment of the anterior deltoid when employing this operative technique.

It is clear that deinnervation or detachment of

the deltoid results in a group of patients who have pain and poor function and who are extremely dissatisfied! Because treatment of this catastrophe is almost certainly doomed, the best approach is prevention. Although positioning the arm in adduction and external rotation may make deltopectoral approaches to the shoulder safer, we strongly recommend identifying the axillary nerve during anterior shoulder procedures and protecting it during the entire procedure. Furthermore, the long anterior deltopectoral incision described by Neer[28, 31] for use in shoulder arthroplasty does not require release of any of the origin of the deltoid. Occasionally, when additional exposure is required, a portion of the insertion of the deltoid may be released.

Loss of the deltoid is the most disabling complication that occurs during shoulder procedures. Treatment of this complication is typically unsatisfactory. Disastrous consequences will occur during surgery if there is not an exact knowledge of the location of the axillary nerve. These same dire circumstances will happen if there is not a secure repair of any detached deltoid muscle.

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