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Outcome of reverse shoulder arthroplasty with pedicled pectoralis transfer in patients with deltoid paralysis

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Background: Management of shoulder arthritis associated with deltoid paralysis can be very challenging. The purpose of this study was to report the outcome of reverse shoulder arthroplasty with pedicled pectoralis transfer to reconstruct the anterior deltoid in patients with symptomatic shoulder arthritis and a paralyzed deltoid.

Methods: This study included 31 patients with an average age of 51 years (range, 27-73 years). All patients had chronic deltoid paralysis with significant loss of function due to progressive arthritis associated with rotator cuff deficiency. All patients underwent reverse shoulder arthroplasty with pedicled pectoralis muscle transfer. Additional transfers were performed in patients with no preoperative external rotation: 5 underwent latissimus transfer, and 3 underwent direct lower trapezius transfer to the infraspinatus.

Results: At an average follow-up of 37 months, 29 patients had significant improvements in pain; the shoulder subjective value; the Disabilities of the Arm, Shoulder and Hand score; and shoulder range of motion, mainly flexion of 83° and external rotation of 15°. Two patients sustained postoperative acromial fractures and had persistent pain after surgery with minimal improvement in shoulder flexion and external rotation. One of them had a failed attempt at open reduction–internal fixation of the acromion.

Conclusion: Reverse shoulder arthroplasty with pedicled pectoralis transfer is a promising procedure that may lead to improved pain and function in patients with shoulder arthritis associated with deltoid paralysis.

Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Pectoralis; axillary nerve; deltoid; paralysis; reverse; shoulder; arthroplasty

Shoulder arthritis associated with deltoid paralysis is a complex pathology associated with damage to the axillary nerve and resultant disabling shoulder dysfunction. Whether iatrogenic or from a prior trauma, the axillary nerve injury and resultant deltoid paralysis lead to poor shoulder motion and possible instability. Patients diagnosed with a combination of deltoid paralysis and shoulder arthritis have very few surgical management options. Deltoid paralysis has traditionally been thought to be a contraindication to anatomic and reverse shoulder arthroplasty (RSA) because of the associated shoulder dysfunction and instability,[2,3,6,12] particularly with reverse arthroplasty in which the deltoid is the main dynamic stabilizer and the functional motor that moves the shoulder.

The treatment options for deltoid paralysis involve nerve transfer,[7,8,13] tendon transfer,[4,5,9] or glenohumeral arthrodesis.[1,10,11]

Institutional review board approval was obtained prior to the study. Each author certifies that his or her institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

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Although isolated deltoid paralysis treated with transfer of a triceps nerve branch to the axillary nerve has shown success in brachial plexus cases without arthritis,[7,8,13] the recovery process takes months to years to see its true effects, and it has not been reported in the setting of progressive glenohumeral joint arthritis. Transfer of the pectoralis major to reconstruct the deltoid has also been described in small case reports[5,9]; however, little is known about the use of these transfers in the setting of arthritis.

To our knowledge, the outcome of RSA with pedicled pectoralis transfer has not been previously reported. The purpose of this study was to report the outcome of RSA and pedicled pectoralis transfer for anterior deltoid reconstruction in patients with symptomatic shoulder arthritis and a paralyzed deltoid.

Methods

Patient population

This study included 31 patients. All patients had chronic deltoid paralysis with significant loss of function due to progressive arthritis associated with rotator cuff deficiency (Fig. 1). All patients underwent RSA with pedicled pectoralis muscle transfer. Additional transfers were performed in patients with no preoperative external rotation: 5 underwent latissimus transfer, and 3 underwent direct lower trapezius transfer to the infraspinatus.

We retrospectively reviewed 31 shoulders in 31 patients (Table I). There were 22 men and 9 women; the right shoulder was involved in 14 cases and the left in 17. The mean age of the patients was 51 years (range, 27-73 years). All patients had chronic deltoid paralysis from axillary nerve palsy, confirmed on electromyography. They presented with marked loss of shoulder function due to progressive arthritis associated with rotator cuff deficiency. The causes of the axillary nerve palsy were as follows: prior shoulder dislocation (n = 11), prior shoulder open reduction–internal fixation (n = 6), brachial plexus injury with no prior nerve transfer (n = 3) or with failed prior nerve transfer (n = 6), prior arthroscopic shoulder osteocapsular arthroplasty with iatrogenic nerve injury (n = 3), and prior gunshot wound (n = 2) (Table II). Of note, in 4 of the 11 patients with prior shoulder dislocation, the injury occurred more than 20 years before presentation.

On examination, gross inspection of the shoulder musculature showed atrophy of all 3 parts of the deltoid (anterior, middle, and posterior), with a positive sulcus sign (+1 in 21 patients, +2 in 6 patients, and +3 in 4 patients). All patients had normal scapulothoracic function. Shoulder flexion and abduction were very limited (average, 15°; range, 0°-30°) (Fig. 2). The findings of the Jobe test were positive

Table I Patient demographic characteristics

Characteristic	Data
Age, y	51 (range,27-73)
Sex, n	
Male	22
Female	9
Affected shoulder, n	
Right	14
Left	17
Tobacco use, n	
Yes	6
No	25
Diabetes, n	
Yes	3
No	28
BMI	28.2 (range,23-37)

BMI, body mass index.

Table II Cause of axillary nerve injury

Cause	n
Prior shoulder dislocation	11
Prior ORIF	6
Brachial plexus injury with no nerve transfer	3
Brachial plexus injury with failed nerve transfer	6
Prior arthroscopic osteocapsular arthroplasty with iatrogenic nerve injury	3
Gunshot wound	2

ORIF, open reduction–internal fixation.

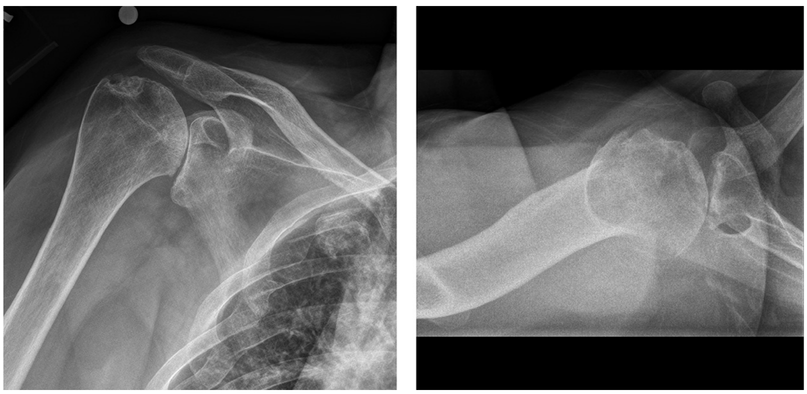

Figure 1 Anteroposterior and axillary radiographic views showing advanced arthritis with proximal migration of the humeral head associated with posterior subluxation in the setting of complete chronic deltoid paralysis.

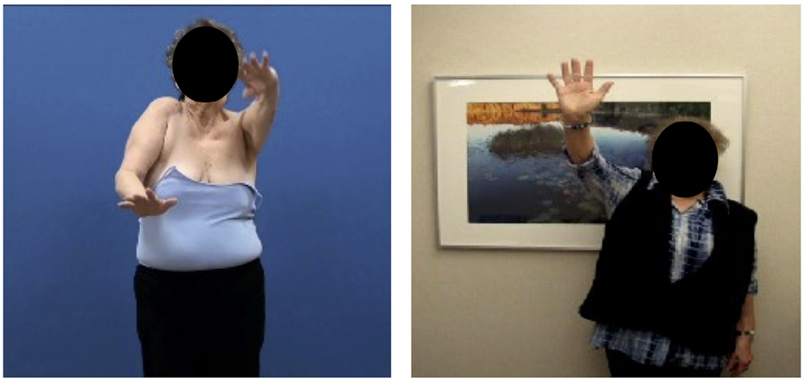

Figure 2 **(A)** Preoperative examination of patient with advanced glenohumeral arthritis, chronic complete deltoid paralysis, and limited shoulder flexion to 10°. **(B)** Patient's postoperative ability to achieve flexion of greater than 100° at 31 months.

in all patients because of either rotator cuff deficiency or paralysis. Shoulder external rotation was completely deficient in 8 patients, whereas average shoulder external rotation for the rest of the patients was 20° (range, −20° to 40°). The findings of the belly-press test were positive in 12 patients, negative in 15, and equivocal in 4. The patients' pain levels were evaluated as none, mild, moderate, or severe. When patients were asked about any associated pain with attempted range of motion, the pain was localized to the shoulder region, primarily around the glenohumeral joint. The shoulder subjective value (SSV) and Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire were completed preoperatively. On examination of the shoulder girdle muscles, all patients had normal pectoralis major function, which was tested with resisted adduction of the arm against the chest.

Surgical technique

All patients underwent RSA with pedicled pectoralis muscle transfer. Additional transfers were performed in patients with no preoperative external rotation: 5 underwent latissimus transfer, and 3 underwent direct lower trapezius transfer to the infraspinatus (Table III). The indications for surgery included (1) persistent symptomatic chronic deltoid paralysis associated with variable degrees of degenerative arthritis of the shoulder and rotator cuff insufficiency; (2) patients who were not candidates for nerve repair or reconstruction or who had a prior failed reconstruction; and (3) failure of conservative management, including physical therapy involving strengthening and range-of-motion exercises.

All patients who did not require additional lower trapezius transfer for shoulder external rotation were positioned in the beach-chair position. Otherwise, patients who required lower trapezius transfer were positioned in the lateral position.

Table III Types of procedures performed

	n
Procedure	
Pedicled pectoralis with RSA	13
Pedicled pectoralis with latissimus transfer and RSA	5
Pedicled pectoralis with lower trapezius transfer and RSA	3
Total	21

RSA, reverse shoulder arthroplasty.

A large curved incision is performed starting approximately 2 cm distal to the sternoclavicular joint, extending laterally along the lower border of the palpable clavicle toward the acromioclavicular joint and then distally toward the deltoid insertion near the deltopectoral interval. Large skin flaps are developed, and the pectoralis major muscle is exposed. The muscle is usually divided into 3 parts: clavicular origin, upper part of the sternal origin, and lower part of the sternal origin (Fig. 3, *A*). The innervation for the clavicular origin and upper part of the sternal origin originates from the superior pectoral nerve, and it is separate from the innervation of the lower part of the sternal origin, which originates from the middle and lower pectoral nerves (Fig. 4). In most cases, there are 3 sources of blood supply to the pectoralis major: the superior thoracic artery (variable, usually only to the clavicular origin); the thoracoacromial artery, which is the main blood supply to the clavicular origin and upper part of the sternal origin; and the lateral thoracic artery, which mainly supplies the lower part of the sternal origin. Harvesting of the pectoralis major is based on these neurovascular bundles (Fig. 4). Transfer of the pedicle flap is begun by detaching the upper part of the sternal origin and the entirety of the clavicular origin from the sternum and clavicle. It is important to be cautious around the pedicle, located distal to the midclavicle, and to avoid dissection distal to the midclavicle before elevation of the muscle. Once the muscle is detached from its origin, the insertion into the humerus is detached and the muscle elevated, allowing for visualization and mobilization of the pedicle proximally to the level of the axillary artery and vein (Fig. 3, *B-D*). Once the muscle has been mobilized and prepared, it is protected with moist gauze during RSA.

RSA is then performed in the standard fashion. It is important to reattach the subscapularis if possible. In addition, in patients who require a tendon transfer for shoulder external rotation, we perform a latissimus transfer if the tendon is available and not damaged from previous surgery. In brief, the latissimus tendon is easily identified distal to the humeral head and is separated from the underlying teres major, detached, and tagged with 2 No. 2 nonabsorbable sutures in Krackow fashion. The tendon is then dissected more distally to obtain sufficient excursion, transferred posterior around the proximal humerus, and attached to the level of the teres minor insertion.

If the lower trapezius is used for transfer, the patient is usually positioned in the lateral position to facilitate the harvest. A vertical incision is performed just medial to the spine of the scapula and

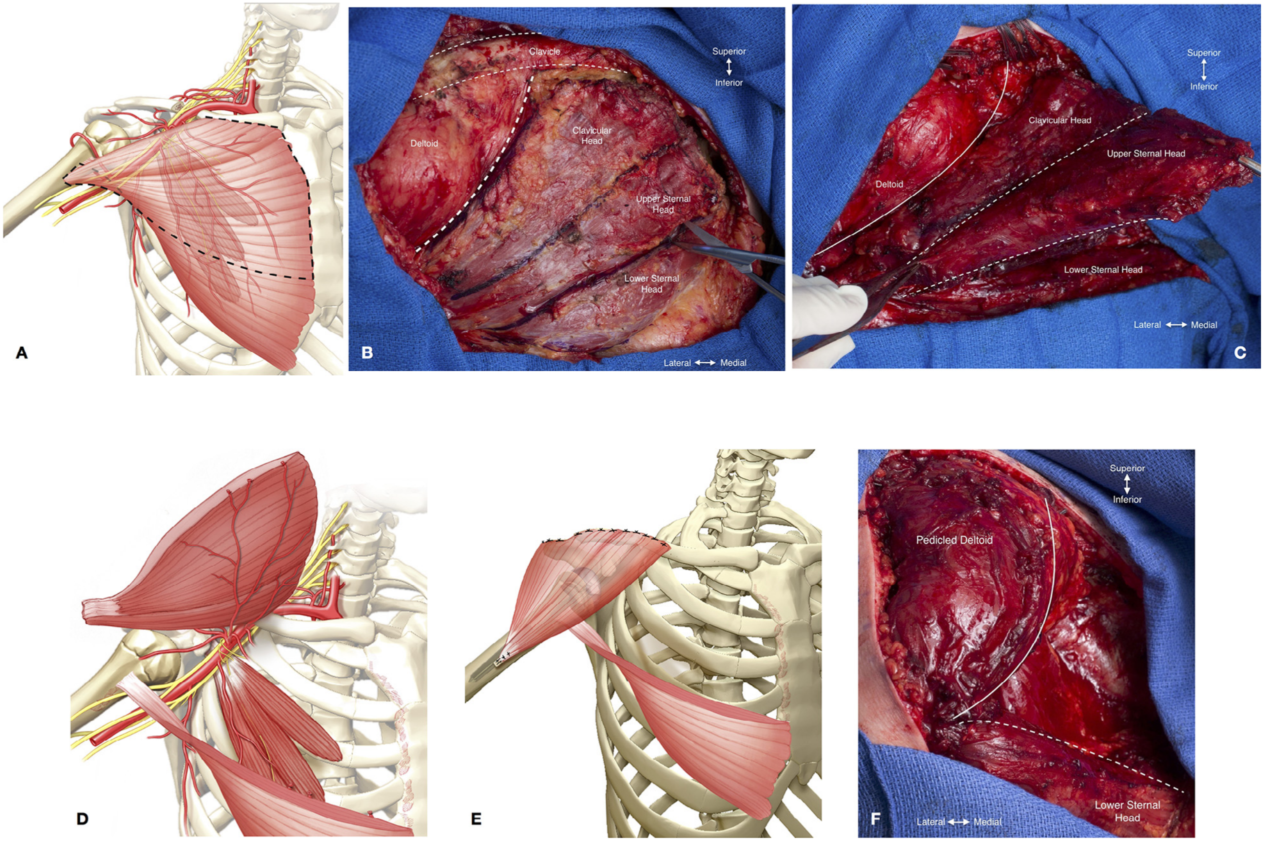

Figure 3 **(A)** Pectoralis with its underlying neuroanatomy. **(B)** Intraoperative exposure of the pectoralis major showing its 3 parts: clavicular origin, upper sternal origin, and lower sternal origin. The scissors indicate the interval between the upper and lower sternal origins. **(C)** Intraoperative detachment of the origin of the clavicular and upper sternal origins. **(D)** Further detachment of the pectoralis from its insertion with elevation of the muscle pedicle over the neurovascular bundle. **(E)** Appearance of the pedicled pectoralis after proximally attaching it to the lateral third of the clavicle on the anterior acromion and distally attaching it to the humerus at the level of the deltoid insertion. **(F)** Intraoperative picture of pedicled pectoralis. (By permission of Mayo Clinic. All rights reserved.)

extended distally approximately 5 cm. The lateral border of the lower trapezius is identified and followed to the level of the insertion on the medial scapula where it is detached, and the tendon is tagged with No. 2 nonabsorbable sutures in Krackow fashion. Further dissection is performed medially to obtain full excursion of the muscle. Next, an Achilles tendon allograft is obtained, and the thin portion of the allograft is repaired to the lower trapezius with multiple No. 2 nonabsorbable sutures. The muscle is now ready for transfer. A tunnel is created between the medial wound and the anterior wound, and the tendon is passed and repaired to the lateral aspect of the footprint of the infraspinatus. We usually place 2 No. 2 nonabsorbable sutures in Krackow fashion in the thick portion of the allograft and perform the repair using proximal humeral buttons (Arthrex, Naples, FL, USA) while the shoulder is in 40° of external rotation.

In preparation for performance of the pedicled pectoralis transfer, the anterior atrophic deltoid is excised and the lateral third of the clavicle and anterior aspect of the acromion are debrided with an electrical burr to create a healthy bleeding bed. Multiple No. 2 nonabsorbable sutures are placed through transosseous tunnels in the prepared clavicle and acromion (usually around 6-8 double sutures). A trough in the humerus is created just anterior to the deltoid insertion for the tendon repair. The muscle is flipped (similar to turning a page in a book) so that the most medial portion is transposed laterally (Fig. 3, *D*). While the shoulder is kept in approximately 60° of flexion, the proximal aspect is repaired to the clavicle and acromion and the distal tendon is repaired using proximal humeral buttons (Arthrex), which are reinforced with further soft-tissue sutures (Fig. 3, *E* and *F*). To maintain the resting muscle length, 2 separate sutures are placed on the surface of the muscle separated by 6 cm before the muscle detachment, and this distance is maintained during tensioning and reattachment of the muscle.

A drain is placed prior to a layered subcuticular incision closure. The patient uses a premade custom shoulder brace that is aimed to position the shoulder in 60° of flexion with resting internal rotation (Fig. 5). If tendon transfer is performed for external rotation, then the brace is adjusted to have 60° of flexion in addition to 40° of external rotation.

Postoperative management

The patient strictly uses the brace for 8 weeks. The drain is removed when there is drainage of less than 30 mL over a 24-hour period, and antibiotics are maintained while the drain is in place. After 8 weeks, the brace is discontinued and physical therapy started. Physical therapy consists of active-assisted range of motion with pool therapy for 8 weeks. At 4 months, gentle strengthening is started and is performed for 8 weeks, followed by activity as tolerated with a limitation

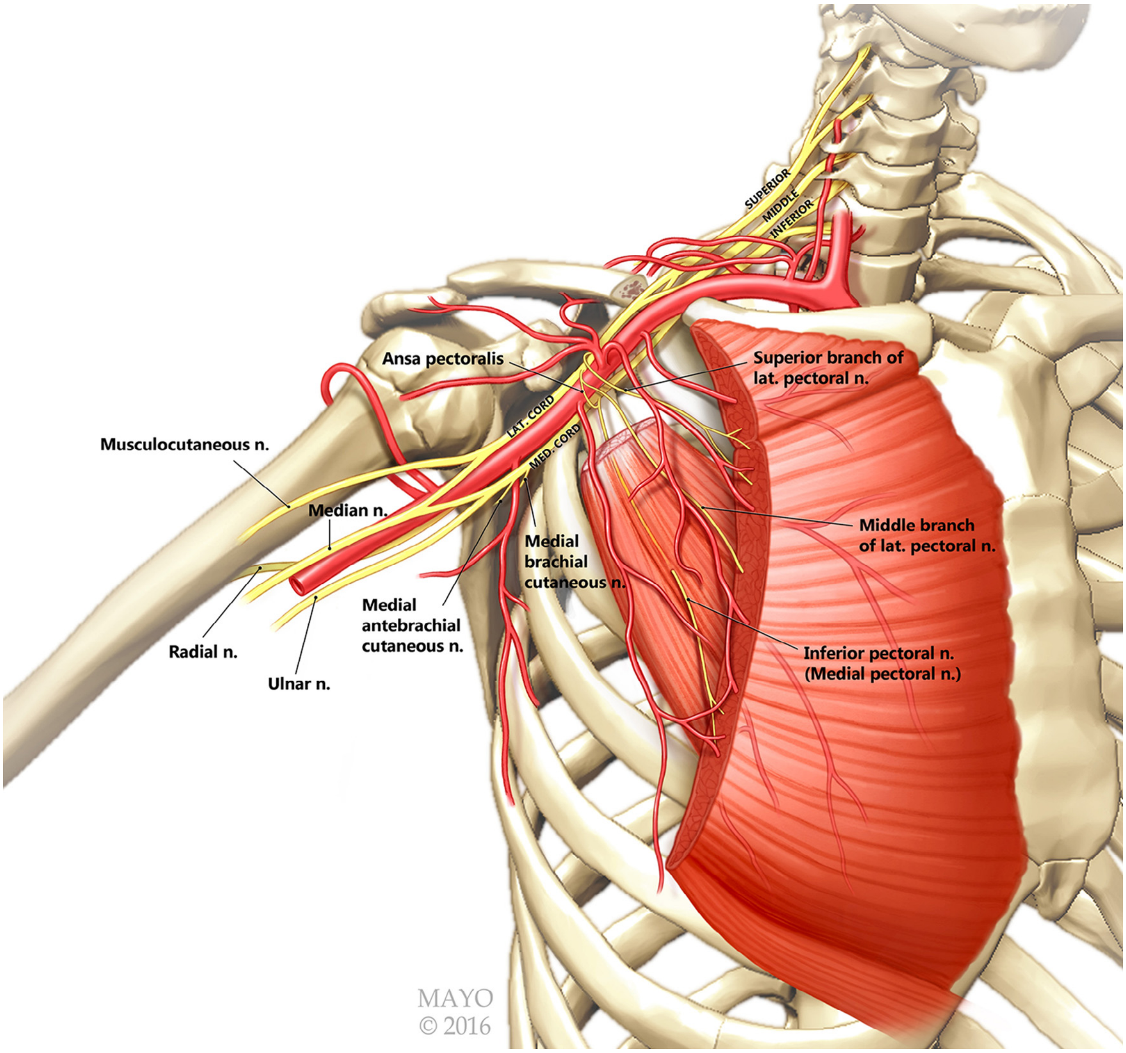

Figure 4 Anatomic details of pectoralis major muscle with its neurovascular supply. lat, lateral; n, nerve. (By permission of Mayo Clinic. All rights reserved.)

of a 15-lb maximum in any direction. Passive stretching of the shoulder in any direction should be avoided for at least 5 months postoperatively to avoid injury to the muscle transfer.

Statistical analysis

Descriptive statistics were used to summarize data, with categorical data summarized as percentages and counts and continuous data as interquartile ranges. The differences between preoperative and postoperative data were compared using the 2-sample Fisher exact test for categorical variables or the Student *t* test of unequal variance for continuous and categorical variables.

Results

At an average follow-up of 37 months (range, 13-73 months), 29 patients (78%) had no or mild pain, which represented a significant improvement in pain from their preoperative values ($P < .01$) (Table IV). The mean SSV improved from 7% preoperatively to 53% postoperatively ($P < .01$). The mean DASH score improved from 54 preoperatively to 33 postoperatively ($P < .01$). Radiographs were obtained and showed stable RSA in all patients without any signs of glenoid or humeral component loosening (Fig. 6).

Table IV Outcomes

	Preoperative	Postoperative
Range of motion, °		
Elevation	15 (range, 0-30)	83 (range, 50-110)
Abduction	12	20
External rotation	Completely deficient in 8 patients; 20 (range, −20 to 40) in remaining patients	16 (range, 5-30)
SSV	7%	53%
DASH score	54	33

DASH, Disabilities of the Arm, Shoulder and Hand; SSV, shoulder subjective value.

Figure 5 Custom-made brace in flexion and internal rotation. The patient remains in this brace for 8 weeks postoperatively.

On examination, patients had noticeable improvements in their shoulder range of motion, specifically shoulder flexion, which improved from a mean of 11° preoperatively to a mean of 83° (range, 50°-110°) postoperatively ($P < .01$) (Table IV). There was no significant improvement in shoulder abduction, from 12° preoperatively to 20° postoperatively ($P = .54$). Shoulder external rotation improved from a mean of 3° preoperatively to a mean of 16° (range, 5°-30°) postoperatively ($P = .03$).

Postoperative complications included acromial fractures at the junction of the acromion and scapular spine in 2 patients. Both had persistent pain after surgery with minimal improvement in shoulder flexion and external rotation. One of these patients underwent open reduction–internal fixation at 4 months postoperatively. Although fracture union was achieved, the patient continued to have marked pain and limitations in shoulder function. The other patient with an acromial fracture decided to pursue nonoperative treatment but continued to have persistent shoulder pain and limited shoulder function. Both patients elected to pursue no further treatment.

Discussion

Axillary nerve injury leading to deltoid dysfunction is a very complex and difficult pathology to treat, particularly in the setting of advanced glenohumeral arthritis. Given the dependence of all shoulder arthroplasty prostheses on a functional deltoid,[2,3,6,12] surgeons are left with few salvage options. Although the indications for RSA have markedly expanded in recent years, it is contraindicated in the setting of deltoid paralysis, as the biomechanical function and implant stability of this prosthesis are dependent on a functional deltoid. Nerve transfers have shown promise in improving deltoid function; however, these often take more than 1 year to see their full functional benefit, have variable results in regaining full deltoid strength, and are contraindicated if the injury occurred more than 6 to 9 months prior to the time of patient evaluation.[7,8,13] Alternatively, the pedicled pectoralis muscle transfer has a more immediate and potentially profound effect,[5,9] possibly allowing for its use with the reverse prosthesis. In this case series, we attempted to provide evidence of the role of the pedicled pectoralis muscle transfer used concomitantly with the reverse prosthesis, demonstrating its potential efficacy in treating advanced glenohumeral arthritis in the setting of deltoid dysfunction.

In our series of 31 patients with symptomatic shoulder arthritis and deltoid paralysis who underwent RSA and pedicled pectoralis transfer, 78% of patients achieved marked pain relief and improvements in shoulder function. Postoperative flexion improved to beyond 80°, whereas patients were able to externally rotate their arms 15° beyond neutral. However, 2 of the patients who did not achieve satisfactory outcomes sustained a postoperative acromial fracture; this particular complication had detrimental effects associated with the

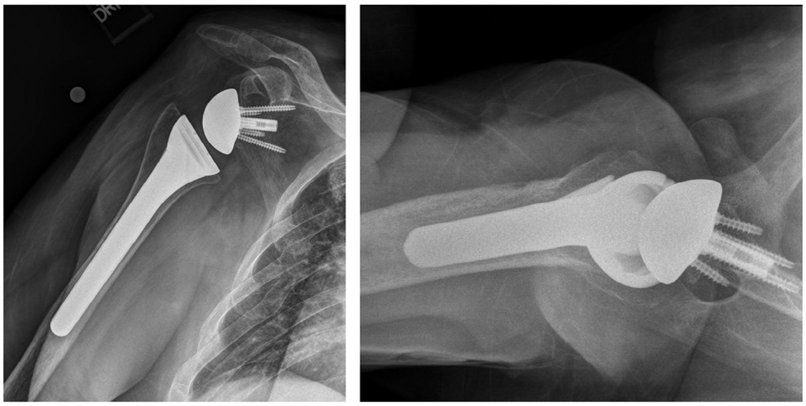

Figure 6 Postoperative anteroposterior and axillary radiographic views of same patient in Figure 1 showing reverse arthroplasty in good position.

function of this muscle transfer. We believe the causes of the fractures are multifactorial. Tension on the paralyzed deltoid and surrounding tissues might be one reason. We can still tension the reverse prosthesis with a paralyzed deltoid because the remaining atrophic scarred deltoid and surrounding tissues can still maintain the tension. Tensioning of the transferred pectoralis major is another factor. In addition, the patients with paralysis usually have very osteopenic bone around the area of the paralyzed shoulder with the added multiple transosseous tunnels in the acromial area, which may also place the acromion at risk of fracture.

Surgical treatment options for axillary nerve palsy leading to deltoid paralysis include nerve transfer,[7,8,14] tendon transfer,[4,5,9] or glenohumeral arthrodesis.[1,10,11] In 2003, Leechavengvongs et al[8] described nerve transfer involving the radial branch to the long head of the triceps transferred to the deltoid branch of the axillary nerve. They reported that all 7 patients achieved muscle grade 4 (M4, deltoid power against resistance) at last follow-up, with average shoulder abduction of 124° and no notable triceps weakness. Subsequent studies have validated this nerve transfer as an option for restoration of deltoid function after axillary nerve palsy.[7] However, recovery of any deltoid muscle function does not happen until between 6 and 8 months after surgery,[7,8] with useful shoulder function recovering up to 1.5 to 2 years postoperatively. Furthermore, there have not been any studies that have examined the efficacy of this transfer in the setting of advanced shoulder arthritis. Therefore, the usefulness of this nerve transfer with concomitant glenohumeral arthroplasty reconstruction is unclear.

Glenohumeral arthrodesis is another option for patients with deltoid paralysis and glenohumeral osteoarthritis. This option depends solely on scapulothoracic motion for shoulder motion, which allows the patient to elevate to reach the face and extend to reach the back pocket.[11] In their series, Cofield and Briggs[3] concluded that shoulder arthrodesis provided effective pain relief and shoulder stabilization. This procedure, however, depends on intact periscapular muscles and limits internal and external rotation. It can also be difficult to achieve fusion in situations with significant bone loss.

The pectoralis major tendon transfer for deltoid paralysis was first reported in a study by Hou and Tai[5] in 1991, in which 7 patients underwent transfer of the upper portion of the pectoralis either alone (4 patients) or combined with upper trapezius transfer (3 patients). When this technique was used alone (without shoulder replacement), the average abduction achieved was 40°. However, when upper trapezius transfer was added, the average abduction achieved was 70° to 90° and forward flexion was 60° to 150°. Later, in 2009, Lin et al[9] reported similarly encouraging results in patients with brachial plexus injuries. At a mean follow-up of 6 years, 8 patients achieved mean abduction of 74° and forward flexion of 75°, while subluxation was eliminated in all 8 patients. However, to date, there have not been any reports on the use of this transfer in the setting of advanced glenohumeral arthritis or concomitantly with any shoulder prosthesis. In our series, when combined with RSA, the pedicled pectoralis muscle transfer achieved predictable pain relief, with mean shoulder flexion of 83° and external rotation of 15°. Patients had reasonable postoperative SSV and DASH scores.

In addition to their report on pectoralis major transfer outcomes, Hou and Tai[5] redefined the functional anatomy of the pectoralis major muscle, showing that it has 3 parts: clavicular (origin on the clavicle), sternocostal (origin in the first to sixth sternocostal regions), and abdominal (origin at the junction of the lower sternocostal and rectus abdominis fascia). These 3 separate origins converge to insert on the lateral lip of the biceps groove of the humerus as anterior (clavicular and upper sternocostal portions) and posterior (lower sternocostal portions) tendons. The upper part of the pectoralis major is supplied by the thoracoacromial artery and innervated by the lateral pectoral nerve, whereas the lower part is supplied by either the thoracoacromial artery or the internal thoracic branch of the axillary artery and is innervated by the medial pectoral nerve. These separate blood supplies and innervations make this pedicled muscle transfer feasible. During transfer of the pectoralis major muscle, the upper portion is harvested on its pedicle; the muscle is then turned over 180° with the deep surface now superficial; the muscular portion is attached to the lateral clavicle and acromion, while the tendinous portion is anchored to a bony groove near the deltoid tuberosity. This re-creates the anterior deltoid in a close-to-anatomic fashion.

Given the re-creation of the anterior deltoid by the upper portion of the pectoralis major muscle, as well as the immediate functional gains seen with tendon transfers, it makes this tendon transfer a potentially ideal option to be used concomitantly with the reverse prosthesis. As seen in our series, patients regain shoulder stability and function, with the gradual retraining of the upper pectoralis major muscle. Functioning in a similar fashion to the anterior deltoid, this tendon transfer provides similar biomechanical advantages when using the reverse prosthesis.

The findings of this study should be taken in light of its inherent limitations. First, it is a retrospective case series and thus lacks prospective data collection and any comparison groups. This limits our ability to compare the pectoralis major transfer with nerve transfers or any forms of other accepted treatments. In addition, the study was performed on a relatively small sample size with a wide age range, varied demographic characteristics, and a variable follow-up time. This is in part because of the relatively low number of patients with deltoid dysfunction and advanced shoulder arthritis, as well as the paucity of studies examining tendon transfers combined with RSA.

Conclusion

The pedicle tendon transfer of the upper portion of the pectoralis major performed concomitantly with the use of a reverse shoulder prosthesis may lead to good outcomes for patients with deltoid paralysis and end-stage arthritis. However, this transfer does have the potential complication of postoperative acromial fractures that could alter the patient's recovery of function and pain relief. Longer follow-up is needed to confirm the stability of the good outcomes of this reconstruction.

Disclaimer

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