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ORIGINAL RESEARCH

Restoration of Shoulder Abduction after Radial to Axillary Nerve Transfer following Trauma or Shoulder Arthroplasty

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ABSTRACT

Purpose: A loss of active shoulder abduction due to axillary nerve dysfunction may be caused by brachial plexus or isolated axillary nerve injury and is often associated with a severe functional deficit. The purpose of this study was to evaluate retrospectively the restoration of deltoid strength and shoulder abduction after transfer of a branch of the radial nerve to the axillary nerve for patients who had sustained an axillary nerve injury.

Materials and methods: We retrospectively reviewed all patients who underwent transfer of a branch of the radial nerve to the anterior branch of the axillary nerve at our institution, either alone or in combination with other nerve transfers, between 2004 and 2011. We identified, by chart review, 12 patients with an average follow-up of 16.7 months (6-36 months) who met inclusion criteria.

Results: Active shoulder abduction significantly improved from an average of 9.6° (0-60°) to 84.5° (0-160°) ($p < 0.005$). Average initial deltoid strength significantly improved from 0.3 (0-2) on the M scale to an average postoperative deltoid strength of 2.8 (0-5) ($p < 0.005$). Five of 12 (41.7%) achieved at least M4 strength and eight of 12 (66.7%) achieved at least M3 strength. No statistically significant difference was seen when subgroup analysis was performed for isolated nerve transfer *vs* multiple nerve transfer, mechanism of injury with MVC *vs* shoulder arthroplasty, age, branch of radial nerve transferred, or time from injury to surgery. No significant change in triceps strength was observed with an average of 4.9 (4-5) strength preoperatively and 4.8 (4-5) postoperatively ($p = 0.34$). There were three patients who achieved no significant gain in shoulder abduction or deltoid strength for unknown reasons.

Conclusion: Transfer of a branch of the radial nerve to the anterior branch of the axillary nerve is successful in improving deltoid strength and shoulder abduction in most patients. Our series, the largest North American series to our knowledge, has not shown outcomes as favorable as other series. Larger multicenter trials are needed.

Type of study/Level of evidence: This is a retrospective case series representing a level IV study.

Keywords: Brachial plexus, Axillary nerve, Radial nerve, Shoulder abduction, Neurotization.

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INTRODUCTION

Injuries to the axillary nerve or brachial plexus are common and have multiple etiologies including penetrating trauma, traction injuries, brachial plexus birth palsy, shoulder dislocation, and complications of shoulder arthroplasty. The resulting lack of shoulder abduction due to deltoid dysfunction (Fig. 1) can result in a severe functional deficit for patients, making many activities of daily living difficult or impossible.

Many treatment options exist for treating brachial plexus or axillary nerve injuries including plexus exploration with neurorrhaphy, nerve grafting, nerve transfers, tendon transfers and arthrodesis. A recent meta-analysis by Garg et al showed more favorable outcomes with nerve transfers over neurorrhaphy and nerve grafting.[1] Among these, transfer of a branch of the radial nerve to the axillary nerve has shown promising results for restoring deltoid strength and shoulder abduction.[2-4]

The purpose of this study was to review our experience in restoring deltoid strength and shoulder abduction by neurotization of a branch of the radial nerve (Fig. 2) to the axillary nerve, as described by Leechavenvongs,[3,5] in patients with a brachial plexus or axillary nerve injury resulting from trauma or shoulder arthroplasty. We hypothesized that transfer of a branch of the radial nerve to the anterior branch of the axillary nerve would significantly improve shoulder function after either traumatic or shoulder arthroplasty-related brachial plexus or axillary nerve injury. To our knowledge, this is the largest North American case series.

MATERIALS AND METHODS

Following approval by our Institutional Review Board, we performed a search of our institution's perioperative

Fig. 1: Preoperative shoulder posture

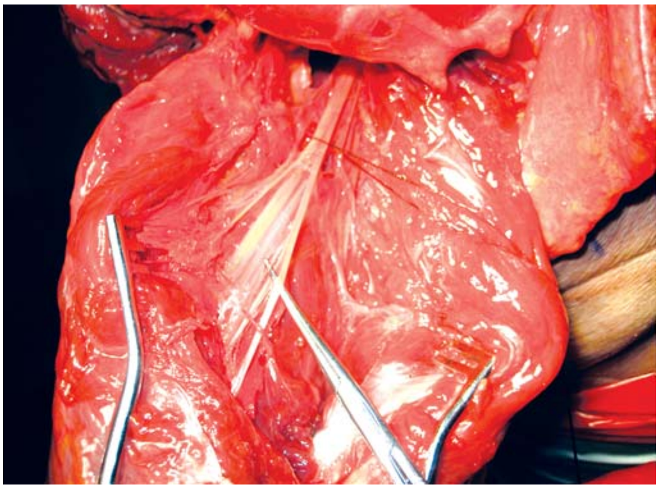

Fig. 2: Branches of the axillary nerve

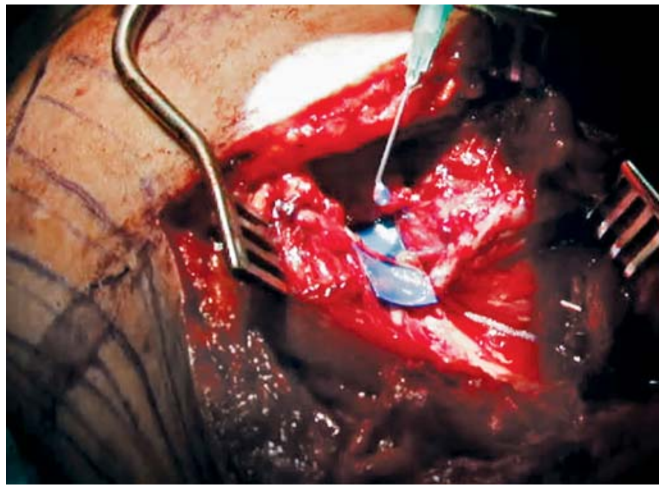

Fig. 3: Neurorrhaphy

database for current procedural terminology (CPT) codes related to surgeries involving radial to axillary nerve transfers done between 2004 and 2011. Patients were included if they had undergone transfer of a branch of the radial nerve to the axillary nerve, were over age 18, had a brachial plexus or axillary nerve injury with deltoid denervation as demonstrated by EMG, had no prior plexus surgeries, had an interval of less than 1 year between injury and surgical nerve transfer, had greater than 6 months follow-up, and had a functioning radial nerve as demonstrated by M4 or 5 triceps strength preoperatively. Patients who had concomitant nerve transfers including spinal accessory nerve to suprascapular nerve and ulnar nerve fascicles to musculocutaneous nerve were included.

Patient charts were reviewed for demographic data including age, gender, date of injury, mechanism of injury, and time to surgery; clinical data including initial strength and range of motion (ROM) assessments; operative data including procedures performed and complications; and follow-up data including length of follow-up and final strength and range of motion assessments (Table 1). All assessments were performed by the treating surgeons. Strength was assessed according to the British Medical Research Council grading scheme.[6] Shoulder abduction was measured by the treating attending surgeon with a goniometer and was defined as the angle between the arm axis and the thoracolumbar spine. There was no validated functional outcome data available.

Twelve patients who had undergone transfer of a branch of the radial nerve to the anterior branch of the axillary nerve satisfied inclusion criteria. There were 11 males and one female with an average age of 39.6 years (20-64 years). The most common etiology was motor vehicle collision (MVC)[8] but other etiologies included shoulder hemiarthroplasty (2), total shoulder arthroplasty (1), and unknown (1). Six patients had an isolated axillary nerve palsy, and 6 patients had more proximal upper trunk injuries as confirmed by EMG (Table 1). The average interval from injury to surgery was 6.6 months (4-11 months). The branch of the radial nerve to the lateral head of the triceps was transferred in three patients, the branch to the long head in eight patients, and the branch to the medial head in one patient. Five patients had additional nerve transfers. Four of those patients had spinal accessory nerve to suprascapular nerve transfer and motor fascicles of the ulnar nerve to the musculocutaneous nerve transferred in the brachium. One patient had only the addition of the spinal accessory to suprascapular nerve transfer. The minimum follow-up was 6 months with an average of 16.7 months (6-36 months).

Our surgical technique used a posterior approach to the shoulder with transfer of a branch of the radial nerve to the triceps to the anterior branch of the axillary nerve (Fig. 3), similar to the technique described by Leechavengvongs.[3] Other nerve transfers were performed based on the patients' injury pattern and functional needs. We routinely used a nerve stimulator to confirm the identity of the anterior branch of the axillary nerve. We used 9-0 nylon with supplemental fibrin glue seal (Tisseel, Baxter Inc, Mississauga, Ontario) for the neurorrhaphy. Postoperatively, a shoulder immobilizer was applied with initiation of pendulum exercises beginning at 10 to 14 days postoperatively. Physical therapy for shoulder mobilization was started when deemed appropriate by the attending surgeon. Patients were seen at 2 weeks, 6 weeks, 3 months, 6 months and 1 year postoperatively.

Statistical analysis for normative data was performed using the paired student t-test function in Excel. The alpha level was set at 0.05.

RESULTS

Shoulder abduction improved from an average 9.6° (0-60°) to 84.5° (0-160°) ($p < 0.005$). Average initial deltoid strength

Table 1: Demographic and clinical data

No.	Age	Gender	Side	Mechanism	Injury	Preop delay (mo)	R to Ax	Radial branch	SA to SS	Oberlin	Follow-up (m)	Preop deltoid (M)	Postop deltoid (M)	Preop shoulder abduction (degrees)	Postop shoulder abduction (degrees)	Triceps postop
1	21	M	L	MVC	Avulsion C5-8	4	X	Lateral	X	X	36	0	4	10	160	5
2	25	M	R	MVC	Avulsion C6	4	X	Lateral	X	X	22	0	0	0	0	5
3	20	M	R		Ax N	11	X	Long			18	0	5	0	160	5
4	48	F	L	MVC	Ax N	8	X	Long			24	0	0	0	0	5
5	21	M	L	MVC	C5-7 injury	6	X	Long	X		22	0	4	0	160	5
6	23	M	L	MVC	Avulsion C5-7	9	X	Long	X	X	27	0	1	0	0	5
7	64	M	L	Hemi	Ax N	8	X	Long			16	0	3	60	150	5
8	45	M	R	MVC	Ax N	8	X	Long			6	0	2	0		
9	54	M	L	MVC	C5-6 injury	4	X	Long	X	X	12	0	3	0	30	4
10	35	M	L	MVC	C5-6 injury	4	X	Medial			6	0	4.5	0	160	5
11	65	M	R	TSA	Ax N	9	X	Lateral			6	1	4	0	60	5
12	54	M	L	Hemi	Ax N	4	X	Lateral			6	2	3	45	50	4

MVC: Motor vehicle collision; Hemi: Shoulder hemiarthroplasty; TSA: Total shoulder arthroplasty; Ax N: Axillary nerve; R to Ax: Radial nerve branch to axillary nerve transfer; SA to SS: Spinal accessory nerve to suprascapular nerve transfer; Oberlin: Motor fascicles of ulnar nerve to musculocutaneous nerve transfer was 0.3 (0-2) on the M scale. Average postoperative deltoid strength was significantly improved at 2.8 (0-5) ($p < 0.005$). Five of 12 patients (41.7%) achieved at least M4 strength, and 8 of 12 patients (66.7%) achieved at least M3 strength.

There were three patients who achieved no functional gain in shoulder abduction or deltoid strength. If the three failures were excluded, average deltoid strength improved from 0.3 (0-2) preoperatively to 3.6 (2-5) ($p < 0.005$) postoperatively, and ROM improved from 12.7° (0-60°) to 116.3° (30-160°) ($p < 0.005$) with five of nine (55.6%) achieving M4 or greater and eight of nine achieving M3 or greater (88.9%). Two of the failures had upper trunk injuries with multiple nerve transfers and one patient had an isolated axillary nerve injury and only a radial to axillary nerve transfer. Further analysis revealed no associations to explain the failures such as age, time to surgery, surgeon performing the procedure, motor branch used or etiology. However, this study was significantly underpowered to detect such associations.

When comparing patients who had isolated radial to axillary nerve transfers (for isolated axillary nerve injury) *vs* multiple nerve transfers (for more proximal trunk injuries), no significant difference was seen in the preoperative strength at 0.4 (0-2) *vs* 0 ($p = 0.3$) or ROM at 15° (0-60°) *vs* 2° (0-10°) ($p = 0.3$), respectively. Likewise, no significant difference was seen in the postoperative strength at three (0-5) *vs* 2.4 (0-4) ($p = 0.5$) or ROM at 96.7° (0-160°) *vs* 70° (0-160°) ($p = 0.6$), respectively. Of note, no patient in the multiple nerve transfer group achieved M5 strength.

Patients with nerve injury from shoulder arthroplasty started with significantly better shoulder abduction at 35° (0-60°) *vs* 1° (0-10°) ($p < 0.01$) for the MVC group. Patients with nerve injury from shoulder arthroplasty also had a trend toward increased strength at 1 (0-2) *vs* 0 (0-1) ($p = 0.055$), respectively. There was no significant difference in final shoulder abduction at 86.7° (50-150°) for the arthroplasty group *vs* 83.7° (0-160°) for the MVC group ($p = 0.98$). Similarly, there was no significant difference in final strength at 3.3 (3-4) for the arthroplasty group *vs* 2.6 (0-4.5) for the MVC group ($p = 0.54$).

There was no significant difference in ROM or strength preoperatively if groups were divided into those younger than age 40 and those overage 40. The younger group ($n = 6$) achieved an average ROM of 106.7° (0-160°). The older group ($n = 6$) achieved an average ROM of only 58.0° (0-150°) but this was not significantly different than in the younger group ($p = 0.3$).

Patients were divided into those who underwent surgical intervention at less than 6 months from injury ($n = 5$) and those who underwent surgical intervention at greater than 6 months from injury ($n = 7$). No significant difference was seen in postoperative strength at 2.9 (0-4.5) for the early group *vs* 2.7 (0-4) for the late group ($p = 0.86$). No significant difference was seen in range of motion at 80° (0-160°) *vs* 88.3° (0-160°) ($p = 0.86$) for the early *vs* late group.

The one patient who underwent transfer of the branch of the radial nerve to the medial head obtained 4.5 strength with final shoulder abduction of 160°. For patients who had the branch to the lateral head transferred ($n = 3$), average postoperative strength was 3.6 (3-4) and ROM was 90° (50-160°). For patients who had the branch to the long head transferred ($n = 8$), average postoperative strength was 2.3 (0-5) ($p = 0.23$) and ROM was 71.4 (0-160) ($p = 0.73$).

There was no significant difference in preoperative and postoperative triceps strength at 4.9 (4-5) and 4.8 (4-5), respectively ($p = 0.34$).

There were no operative complications or infections requiring operative intervention. Of the three failures, one patient went on to have latissimus dorsi and teres major transfer to the posterolateral aspect of the rotator cuff but still failed to regain appreciable shoulder abduction. A second patient went on to have a shoulder fusion. The third patient is tolerating his shoulder disability and declined further surgical intervention.

DISCUSSION

Due to less than optimal outcomes with nerve grafting and prior nerve transfer techniques,[7,8] Witoonchart and Leechavengvongs published an anatomic feasibility study in 2003 investigating transfer of the branch of the radial nerve to the long head of triceps to the anterior branch of the axillary nerve.[2] They found the diameter, number of axons, and the anatomic proximity of the nerve to the long head of the triceps to be acceptable for potential transfer to the anterior branch of the axillary nerve. This was followed up with a retrospective review of 15 patients with complete C5-6 avulsion injuries.[5] Thirteen of 15 obtained M4 and 2 obtained M3, with all having useful function of the deltoid. Mean shoulder abduction was 115°, and there were no failures. This population is quite different from our study in that it was more uniform with patients being generally younger (average age 27 years *vs* 39.6 years in our study) with all injuries related to motor vehicle collisions. Their study also has longer and more uniform follow-up (24-50 months, average 32 months). Bertelli reported on 10 patients with transfer of a branch of the radial nerve to the axillary nerve with average shoulder abduction of 92° (range: 65-120°) with only three of 10 patients obtaining M4 strength.[4] Again, in our study final shoulder abduction was 84.5° (0-160°), average postoperative deltoid strength was 2.8 (0-5) with five of 12 patients (41.7%) achieved at least M4 strength and eight of 12 patients (66.7%) achieved at least M3 strength. Our results were more similar to Bertelli's.

The relatively good outcome of the group with axillary nerve transfer alone shows that a single branch of the radial nerve is sufficient to reinnervate the deltoid and provide active shoulder abduction (final ROM 96.7°). Looking at Leechavengongs' series, none of his patients achieved M5 strength.[3,5] None of our multiple nerve transfer patients achieved M5 strength either. However, one of our isolated axillary nerve injury patients achieved M5 strength. This may speak to the inherent differences between isolated axillary nerve injury patients and patients with more diffuse plexus injuries. The cuff muscles were preserved in the isolated axillary nerve injury group, allowing some initial shoulder abduction and rotation.

Our study was unique in that in included patients with axillary nerve injuries from shoulder arthroplasty. Ladermann documented axillary nerve injuries in nine of 19 (47%) patients undergoing reverse total shoulder arthroplasty and neurologic lesions in 13 of 23 (57%) patients undergoing anatomic total shoulder arthroplasty.[9] Most deficits resolved but with shoulder arthroplasty becoming more common,[10] permanent neurologic deficits will likely become more common as well. We have shown that radial to axillary nerve transfer is effective in restoring both deltoid strength and shoulder abduction in most patients in this group. To our knowledge this is the first case series detailing treatment for unresolved axillary nerve deficits after shoulder arthroplasty.

The major weakness of this study is the low number of patients. Other weaknesses include its retrospective nature, short follow-up, lack of control, and lack of validated outcome data. Because procedures were performed by three surgeons, some technical differences are implied, making interpretation of outcomes less certain. Only 6 month follow-up is available on two patients. This study represents a heterogeneous group with etiologies including both trauma and arthroplasty-related nerve palsies with both single and double nerve transfers. Evaluations were performed by treating surgeons introducing some degree of expectation bias. Nine injuries resulted from trauma and 3 from shoulder arthroplasty, likely representing two distinct groups. Additionally there were multiple different nerve transfers performed. These constitute confounding factors that make interpretation of results difficult. Some degree of initial shoulder abduction could have been from the rotator cuff muscles in the isolated axillary nerve injury group.

This case series adds more weight to the current evidence that nerve transfers, specifically a branch of the radial nerve to the anterior motor branch of the axillary nerve, can provide significant benefit to patients who have sustained brachial plexus and/or axillary nerve injuries. Level I and II multicenter prospective randomized studies with validated outcome scores are needed.

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