DOI: https://dx.doi.org/10.47746/FMCR.2025.6202

Deltoid Neurotization with End-To-Side Neurorrhaphy: A Case Series

Fausto Viterbo[1] | Emiliano Sá Fortes de Araújo[2] | Ryane Schmidt Brock[3] | José Antônio Garbino[4]*

***Correspondence:** José Antônio Garbino

Address: [1]Full Professor of Plastic Surgery Division - São Paulo State University Medical School – UNESP - Botucatu Campus – Botucatu – SP – Brazil; [2]Attending Plastic Surgeon, Fornecedores de Cana Hospital – Piracicaba – SP – Brazil; [3]Plastic Surgeon, Member of the Brazilian Plastic Surgery Society, Master degree in Surgery at São Paulo State University Medical School – UNESP; [4]Coordinator of Clinical Neurophysiology Education Program, Lauro de Souza Lima Research Institute, Bauru, São Paulo, Brazil

E-mail ✉: ja.garbino@gmail.com

Received: 10 April 2025; **Accepted:** 21 April 2025

ABSTRACT

It is widely reported in the literature that Axillary Nerve injuries outcomes may be disappointing. Muscular neurotization, which is the direct implantation of the nerve in the denervated skeletal muscle, is one of the techniques used. We report two cases of axillary nerve injury treated with deltoid muscle neurotization through sural nerve grafting. Our procedures have been performed using end-to-side neurorrhaphies on radial nerve. Both patients showed functional results, uneventful postoperative period and clinically and neurophysiologically deltoid functional gain. Deltoid neurotization showed effective in the management of axillary nerve injuries, either as the main treatment or as an auxiliary procedure to functional recovery.

Keywords: *Axillary, Nerve Lesion, End-To-Side, Neurorrhaphy, Deltoid Neurotization, Neurophysiological Outcome*

Introduction

Brachial plexus injuries represent a difficult-to-handle traumatic event. The incidence of such injuries and the indications for surgery have increased recently (Dubuisson and Kline, 2002). In many centers around the world, surgeons have introduced new microsurgical techniques and reported a variety of different philosophies for the reconstruction of the plexus. Microneurolysis, nerve grafting, neurotizations, recruitment of intraplexus and extraplexus donors, as well as local and free-muscle transfers are used to achieve satisfactory results (Dy *et al*., 2013).

Most of these techniques demand nerves that are less important to be used as donors losing their primary function in order to recover the injury lesion (Dy *et al*., 2013; Sun *et al*., 2014). Viterbo, *et al*. (1992) described the end-to-side neurorrhaphy with significant neurotization results and no damage of the donor nerve.

Following nerve injury there are anatomical and physiological changes that result in a new, different brain organization. The nerve transfers with grafts can remodel this organization - central neural plasticity - toward neurorehabilitation. Lately, it has been shown that the previous nerve transfers with grafts can also improve the results of the further needed reconstruction surgeries of brachial plexus injuries (Sun *et al*., 2014). The authors describe the clinical, surgical and outcome aspects of two patients with traumatic partial injury of the axillary nerve and the upper trunk of braquial plexus, treated with nerve grafts using the end-to-side neurorrhaphy technique.

Method

The axillary nerve has been clinically and electrophysiologically assessed. The electroneuromyography (ENMG) was performed with an equipment Model: Keypoint, 2000, Medtronic. The ENMG was carried out before and after the surgery, including a long-term clinical follow-up at 18 months and after three years. In the postoperative state, in order to record the axillary nerve compound motor action potential (CMAP) two techniques of stimulation were applied to both patients: a) Stimulation of the braquial plexus at Erb's point (routine technique). b) Stimulation of the radial nerve at the graft sites, Figure 1. In both techniques, the CMAP was recorded by surface electrodes and a needle electrode in the deltoid muscle. The needle electrode was employed in order to obtain a more isolated potential of the deltoid muscle.

Case Presentations

Case 1

The first patient was a 42-year-old man who had a motorcycle accident 11 months before the treatment. The deltoid muscle physical examination demonstrated Grade 1 in the Voluntary Muscle Testing (VMT) according to The Medical Research Council Grading Score. Before treatment, the ENMG showed partial lesion of the upper trunk including axillary nerve and slight to moderate lesion in the middle trunk, in which the radial nerve had a slight severity lesion grade.

An incision in the lateral side of the injured upper arm was performed. The radial nerve was dissected and two sural nerve grafts were placed in an end-to-side connection to the nerve with the removal of the epineural window. The distal graft extremities were inserted into the inner part of the deltoid muscle, one in the medium portion and another in the superior one.

The patient demonstrated functional improvement in the postoperative period, with an almost complete abduction of the injured arm after 10 months, and the deltoid physical examination showed Grade 3 in VMT.

After three years, another ENMG was performed in order to specifically evaluate the graft. The axillary nerve CMAP was recorded in both techniques: stimulation of the brachial plexus at the Erb's point and the radial nerve at the spiral groove. In both techniques, the CMAP was recorded by surface electrodes and a needle electrode in the deltoid muscle. The latency was 6.0 ms and the CMAP amplitude was 1.8 mV, Fig. 1. During the stimulation of the radial nerve at the spiral groove, in the graft site, CMAPs have been recorded in both situations with the needle and the surface electrodes. On the surface electrodes, the CMAP amplitude was very reduced while with the needle electrode it was higher (0.6-0.7 mV), and the latencies showed highly increased values crossing the graft site recorded with both electrodes, i.e. 34.7 to 41.2 ms, Fig. 2 and Fig. 3.

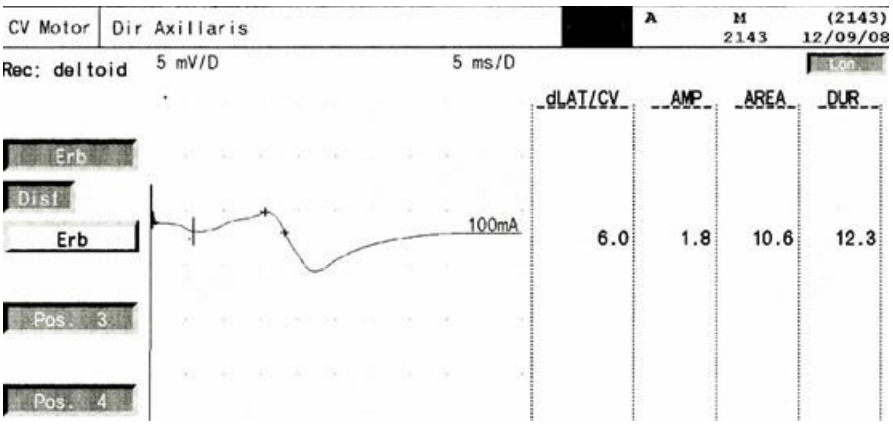

Figure 1: The axillary nerve CMAP recorded by stimulating the brachial plexus at Erb´s point.

Figure 2: Shows the recording at deltoid muscle and stimulating electrodes in the radial nerve at the spiral grove.

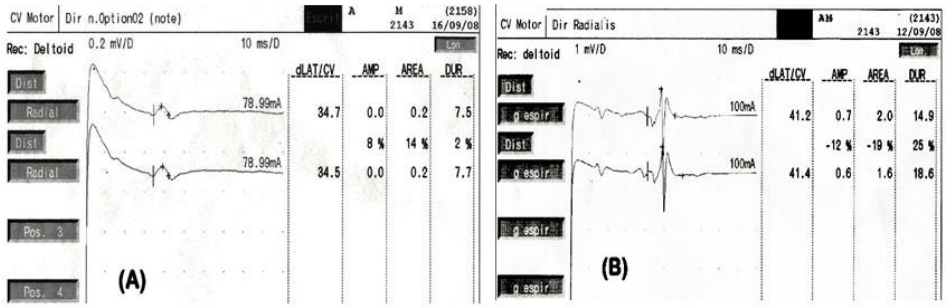

Figure 3: The CMAP recorded by surface electrode (A) and needle electrode (B) in the deltoid muscle during radial nerve stimulation.

These results have demonstrated consistent responses in the deltoid muscle when the radial nerve was stimulated in the arm at the spiral groove level, confirming the connection of the nerve graft and the muscle.

Case 2

The second patient was a 21-year-old man, presenting a brachial plexus injury after a motorcycle accident. He had a right clavicle fracture and impaired right arm function, presenting no movement at first. He started physiotherapy and 3 months after the injury he came in for evaluation. He had improved function on the triceps and a moderate improvement on the biceps, but poor deltoid movement. The deltoid muscle physical examination showed Grade 1 in the VMT. The ENMG demonstrated incomplete brachial plexus upper trunk lesion with pronounced injury and no recorded ongoing reinnervation in the axillary nerve.

The patient was submitted to surgical treatment one month after the interruption of the three-month physiotherapy treatment. He was submitted to deltoid muscle neurotization with two sural nerve grafts coming from the radial nerve. The surgery was performed with an incision in the medial third of the arm to reach the radial nerve and two small incisions were made in the lateral of the arm to reach the deltoid muscle.

End-to-side neurorrhaphies were made with the removal of the epineural window. There were no complications at the postoperative period.

The patient attended physiotherapy sessions and 18 months later he showed great improvement of the deltoid function. At that moment, the deltoid VMT was Grade 4.

The postoperative ENMG exhibited well-developed reinnervation on the right axillary nerve. The CMAP (at the Erb's point) showed higher amplitude under the stimulation at the Erb´s point (5. 3 mV), and the CMAP (at the graft point) with a pronounced reduction of amplitude under stimulation in the medial aspect of the arm on the radial nerve (0.1 mV). The latencies have been 10 times shorter, but the CMAPs amplitudes were not better even with the needle electrode, when compared to the first patient. The graft site was in a shorter distance from the target than it was in the first case.

Discussion

Axillary nerve injury outcomes may be disappointing (Chon and Suk Choi, 2006; Terzis JK *et al*., 1999; Terzis and Papakonstantinou, 2000; Malessy *et al*., 2004). During the acute phase of the injury, the shoulder should rest and when clinically referred, a patient should undergo an extensive rehabilitation program emphasizing the range of motion and the strengthening of the shoulder girdle muscles. If no axillary nerve recovery is observed after 3 to 6 months, surgical procedures may be referred, especially if the mechanism of injury is consistent with a nerve rupture (Perlmutter, 1999).

Muscular neurotization with the direct implantation of the nerve to the target denervated skeletal muscle is one of the techniques used (Hussain *et al*. 2022; Kandenwein *et al*., 2005; Ranalli *et al*., 2008). Our procedures were performed using end-to-side neurorrhaphies to avoid further lesion on the radial (donor) nerve (Viterbo *et al*., 1994).

Had neurotization not being effective in the outcome even with the recovery of the axillary nerve. But, double muscle innervation using end-to-side neurorrhaphy in rats have shown effective in rats (Stipp-Brambilla *et al*., 2012). The neurotization could have also prevented deltoid muscle atrophy while waiting the natural growing of the axillary nerve fibers. Terzis have already described this possibility as the "baby sitter procedure" for facial palsy (Terzis and Tzafetta, 2009). However, interesting differences were seen between both patients. In the first patient, we could see a wider participation of the nerve graft in the deltoid reinnervation when compared to the second one. As we can see, the CMAP recorded by needle electrode obtained by the stimulation at Erb´s point showed an amplitude of 1.8 mV and 0.7 mV stimulating the nerve graft site, Fig. 1 and Fig. 3. Along with the CMAP obtained by the Erb´s point stimulation presented 5.3 mV in amplitude and at the nerve graft site 0.1 mV in the second patient. The explanation could be presumed by the difference in the reinnervation timing between both pathways, natural and graft, suggesting that in the first patient the graft was more efficient than in the second. In the second patient, the reinnervation by the natural pathway reached the targets earlier and became encharged of the majority of muscle fibers, thus leaving less muscle fibers to be innervated by the neurotization. The latencies

discrepancies presented in the first case can be explained by the longer graft needed to go from radial nerve at the spiral grove to deltoid muscle. In addition, greater latencies at certain degree are expected in the conduction across grafts, which is a demyelination and remielinination zone. Actually, both zones showed reliable nerve conduction trough the graft.

Another relevant aspect for rehabilitation in this specific procedure is the neurophysiologic synergy of the axillary and radial nerves, both of which originate at the posterior fascicle and have synergic functions, as the extension of shoulder and arm, respectively. For the choice of the donor nerve, this kinesiology knowledge must be on mind in order to avoid co-contractions and synkinesis caused by activation of antagonists or undesirable muscle groups (Goodisson and Snape, 2000). As end-to-side neurorrahaphy on the donor nerve does not cause any lesion, the authors propose considering this approach as an early nerve procedure in the axillary nerve injury without or only with partial radial lesion.

Conclusion

These findings open the ways to perform variations in the surgical procedure, in terms of graft length and volume, depending on the cases. The length can be reduced by choosing the shorter path from the donor nerve to the receptor. Related to volume, the removed pieces of sural nerve can be added in parallel to the graft according to extension of nerve lesion.

References

Chon SH, Suk Choi MS. Brachial plexus injury with emphasis on axillary nerve paralysis after thoracoscopic sympathicotomy for axillary hyperhidrosis. *Surg Laparosc Endosc Percutan Tech* 2006; 16: 432-434.

Dubuisson AS, Kline DG. Brachial Plexus Injury: A Survey of 100 Consecutive Cases from a Single Service. *Neurosurgery* 2002; 51: 673-683.

Dy CJ, Kitay A, Garg R, Kang L, Feinberg JH, Wolfe SW. Neurotization to innervate the deltoid and biceps: 3 cases. *J Hand Surg Am* 2013; 38: 237-240.

Goodisson D, Snape L. The jaw-winking syndrome. *N Z Dent J* 2000; 96: 58-59.

Hussain T, Khan I, Ahmed M, Beg MSA. Neurotization of musculocutaneous nerve with intercostal nerve versus phrenic nerve - A retrospective comparative study. *Surg Neurol Int* 2022; 13: 305.

Kandenwein JA, Kretschmer T, Engelhardt M, Richter HP, Antoniadis G. Surgical interventions for traumatic lesions of the brachial plexus: a retrospective study of 134 cases. *J Neurosur*g 2005; 103: 614-621.

Malessy MJ, de Ruiter GC, de Boer KS, Thomeer RT. Evaluation of suprascapular nerve neurotization after nerve graft or transfer in the treatment of brachial plexus traction lesions. *J Neurosurg* 2004; 101: 377-389.

DOI: https://dx.doi.org/10.47746/FMCR.2025.6202

Perlmutter GS. Axillary nerve injury. *Clin Orthop Relat Res* 1999; 368: 28-36.

Ranalli NJ, Kline DG, McGarvey ML, Boulis NM, Zager EL. Clinical problem-solving: brachial plexus closed injury and reconstruction. *Neurosurgery* 2008; 62: 1330-1339.

Stipp-Brambilla EJ, Viterbo F, Labbé D, Garbino JA, Bernardelli MM. Double muscle innervation using end-to-side neurorrhaphy in rats. *Sao Paulo Med J* 2012; 130: 373-379.

Sun G, Wu Z, Wang X, Tan X, Gu Y. Nerve transfer helps repair brachial plexus injury by increasing cerebral cortical plasticity. *Regen Res* 2014; 9: 2111-2114.

Terzis JK, Papakonstantinou KC. The surgical treatment of brachial plexus injuries in adults. *Plast Reconstr Surg* 2000; 106: 1097-1122.

Terzis JK, Tzafetta K. The "babysitter" procedure: minihypoglossal to facial nerve transfer and cross-facial nerve grafting. *Plast Reconstr Surg* 2009; 123: 865-876.

Terzis JK, Vekris MD, Soucacos PN. Outcomes of Brachial Plexus Reconstruction in 204 Patients with Devastating Paralysis. *Plast Reconstr Surg* 1999; 104: 1221-1240.

Viterbo F, Trindade JC, Hoshino K, Mazzoni A. Latero-terminal neurorrahaphy without removal of the epineural sheath. Experimental study in rats. *Rev Paul Med* 1992; 110: 267-275.

Viterbo F, Trindade JC, Hoshino K, Mazzoni Neto A. End-to-side neurorrhaphy with removal of the epineurial sheath: an experimental study in rats. *Plast Reconstr Surg* 1994; 94: 1038-1047.