Chapter

Nerve Transfers to Recover External Rotation of the Shoulder after Brachial Plexus Injuries in Adults

Jean-Noel Goubier, Camille Echalier, Elodie Dubois and Frédéric Teboul

Abstract

Restoration of external rotation of the shoulder in adults with partial brachial plexus palsies is challenging. While nerve grafts are possible, nerve transfers are currently the most use method for satisfactory restoration of function. Numerous nerve transfers have been described, although the transfer of the spinal accessory nerve to the suprascapular nerve remains the gold standard. The suprascapular nerve and the nerve to the teres minor muscle are the two preferred targets to restore external rotation of the shoulder. There are numerous nerve donors, but their use obviously depends on the initial injury. The most common donors are the spinal accessory nerve, the rhomboid nerve, branches of the radial nerve, the C7 root fascicle or the ulnar nerve. The choice for the transfer depends on the available nerves and first of all on chosen approach, whether it be cervical or scapular. It also depends on the other associated reconstruction procedures, grafts, or nerve transfers for the recovery of other functions, specifically, elevation of the shoulder and flexion of the elbow. The objective of this chapter is to present the main nerve transfers and to propose a therapeutic strategy.

Keywords: Brachial plexus injury, nerve transfers, shoulder external rotation

1. Introduction

Restoration of external rotation of the shoulder in brachial plexus palsies is challenging. This function, however, is necessary for properly orienting the upper limb for the movements needed in everyday life. While flexion of the elbow and elevation of the shoulder are prioritized for restoration, external rotation of the shoulder should not be neglected. Most of the time, it can be achieved at the same time of operation if nerve transfers are used.

The two nerves mainly targeted for the recovery of this function are the suprascapular nerve (SSN) innervating the infraspinatus external rotator muscle and the branch of the axillary nerve innervating the teres minor external rotator muscle. Several nerve transfers could be proposed due to the large number and variety of lesions of the brachial plexus roots.

2. Most used nerve transfers

2.1 Transfer of the spinal accessory nerve to the suprascapular nerve

Transfer of the spinal accessory nerve (SAN) to the suprascapular nerve (SSN) remains the gold standard for restoring external rotation to the shoulder with nerve transfer (**Figure 1**). This transfer can be carried out in all partial or complete palsies of the brachial plexus, as long as the spinal nerve has not been damaged, which is the case for 96% of brachial plexus injuries [1]. A testing of the trapezius muscle strength is needed before carrying out this transfer. If the trapezius is not scored at least M4, this transfer cannot be undertaken.

This transfer could be carried out via an anterior cervical approach [1] or a posterior scapular approach [2]. The anterior approach is essentially used in the case of a complete palsy of the brachial plexus where an exploration and an possible associated root graft is envisaged. A classical transversal approach of exploration of the plexus may be used as well as the extended approach described by Bertelli [1], allowing improved results with respect to external rotation and abduction of the shoulder. When the anterior cervical approach is used, the anterior branch of the spinal nerve is released and sutured to the origin of the SSN at the beginning of the primary trunk. If the root injury is more distal, the primary trunk may be damaged, and the dissection of the SSN may be difficult, if not impossible. In that case, the suture needs to be made more distally at the level of the coracoid notch and the extended approach of Bertelli [3] becomes necessary.

The results for external rotation were 87 degrees of rotation from the thorax in 40% of patients in a series of 81 patients (**Table 1**). It seems that even with a perfectly optimized nerve transfer, the results are only satisfactory for half of the series.

Certain authors have described, in a case report, the use of the contralateral SAN for SSN restoration using an intercalated graft [4]. The results after 12 months were weak (3 degrees of external rotation), presumably because the use of a graft reduces

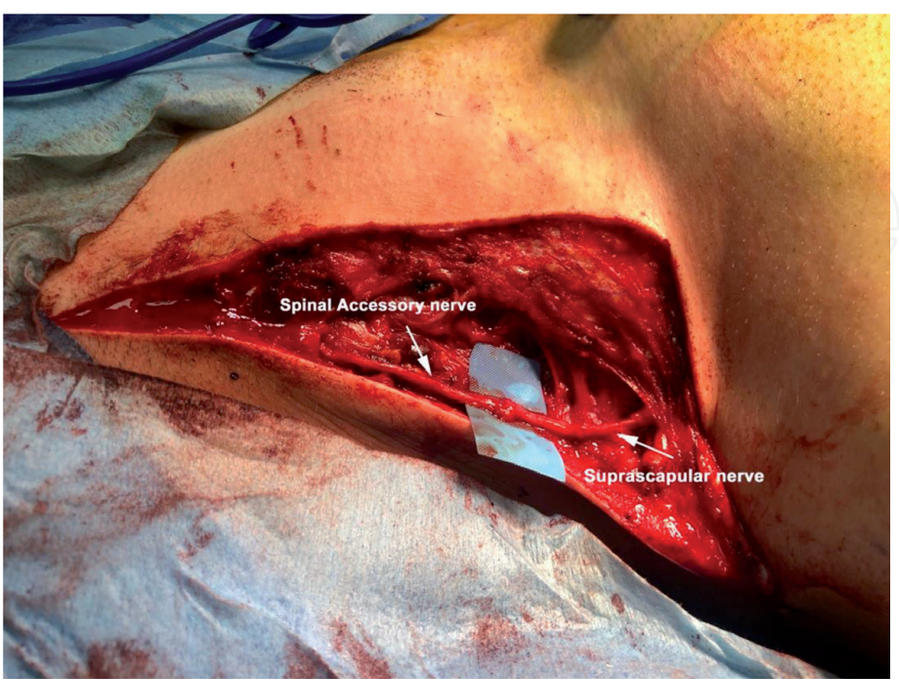

Figure 1.
Transfer of the spinal accessory nerve to the suprascapular nerve in the cervical region by an anterior approach. This approach allows restoration of external rotation and treatment of other deficient functions using grafts of non-avulsed roots (right side).

Donor nerve	Targeted nerve	Author, year	N	Follow up (months)	External Rotation	Time to surgery (months)
Spinal accessory	Suprascapular nerve	Bertelli, 2016 [1]	81	40 (SD 14)	0° - 60%	5,2 (SD 2,4)
					87° (SD 40,6°) - 40%	
		Zermeno-Rivera, 2015 [4]	Case report	12	3°	—
		Yin, 2012 [5]	3	39,2	60° - 70°	4,6 (SD 3,3)
Branch for the rhomboid muscle		Goubier, 2020 [6]	8	32 (25 to 48)	70° to 80° - 38%	—
					90° - 38%	
					100° to 110° - 25%	
Branch of the Radial nerve for the triceps	Nerve for the infraspinatus muscle	Tavares, [7]	9	36	0° - 23%	6,5
					20° to 45° - 44%	
					90° - 11%	
					120° - 11%	
					1 lost of follow up	
Fascicule of the C7 root	Suprascapular nerve	Bertelli, 2004 [8] (Contralateral C7 root)	12 (partial palsy)	36	92° (range 80°-120°)	4,3 (range 2–6)
			12 (total palsy)		75° (range 40° - 100°) - 17%	
					0° - 83%	
		Yin, 2012 [5] (Fascicules of ipsilateral C7 root combined with transfer to post div of the upper trunk)	5	39,2	0°	4,6 (SD 3,3)

Table 1.
Summary of clinical results (external shoulder rotation) stratified by nerve transfer.

the possibility of a direct nerve transfer by reducing the results in terms of delay and extent of recovery. In addition, the exploration and sacrifice of a nerve from the healthy side may be discussed for a brachial plexus palsy.

2.2 Transfer of the rhomboid nerve to the suprascapular nerve

This technique may be used for partial and complete injuries of the brachial plexus [6, 9, 10]. The rhomboid nerve branches comes from the dorsal scapular nerve, the posterior branch of C5. This branch starts relatively proximally and can be damaged in the case of an avulsion of C5. However, it receives the afferents from the C4 root and could, in theory, be used even in the case of an avulsion of the C5 root. The main indication for the rhomboid nerve transfer is a lesion of the SAN. In this case, the transfer could be associated with a transfer of the teres minor nerve from the long triceps nerve or a fascicle of the ulnar nerve (**Figures 2** and **3**).

The rhomboid nerve can be sutured directly to the SSN in the supraspinatus fossa. This technique is carried out using the posterior approach; the suture is close to the infraspinatus muscle, thus encouraging a more rapid recovery. In addition, the posterior dissection eliminates a lesion of the SSN in its passage under the notch and limits the risk of failure of a more proximal suture. The results from our series show that external rotation is recovered. The extent of the results, however, is a little bit less than that of a transfer from the spinal nerve (**Table 1**) [6].

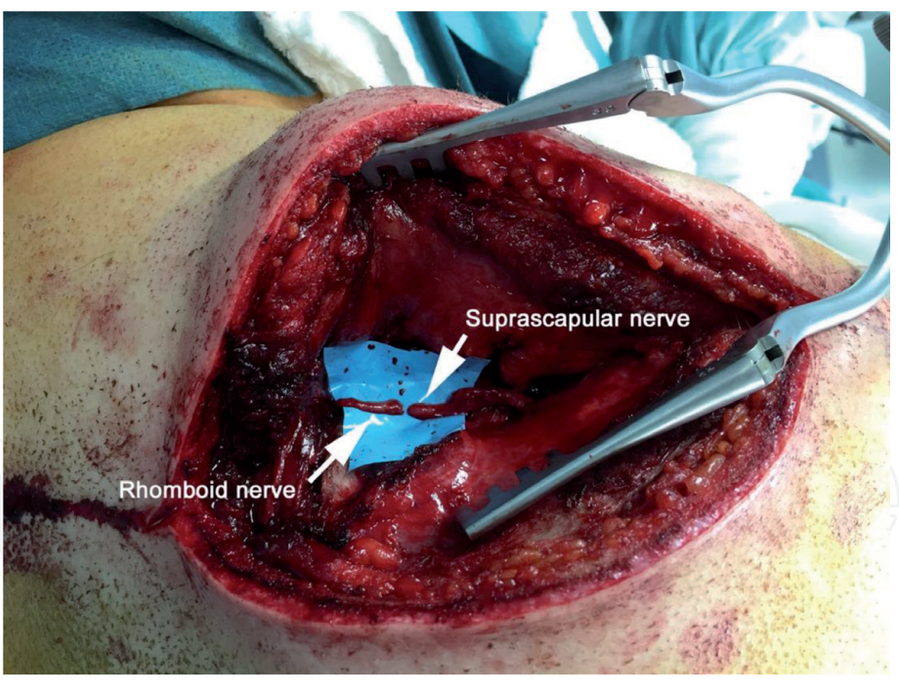

Figure 2.
Transfer of the rhomboid nerve to the suprascapular nerve: The levator scapulae is released from the medial border of the scapula to expose the dorsal scapular nerve. The nerve to the rhomboid muscle is released until it reaches the upper edge of the rhomboid muscle, divided, and then turned toward the suprascapular nerve in the supraspinatus fossa (right shoulder) (courtesy of Elsevier [9]).

2.3 Transfer of the long head of the triceps nerve to the teres minor nerve

This nerve transfer only applies to cases where there are partial lesions of the brachial plexus with preservation of a triceps scored at least M4. This technique is best suited to an axillary approach. The branch of the radial nerve leading to the

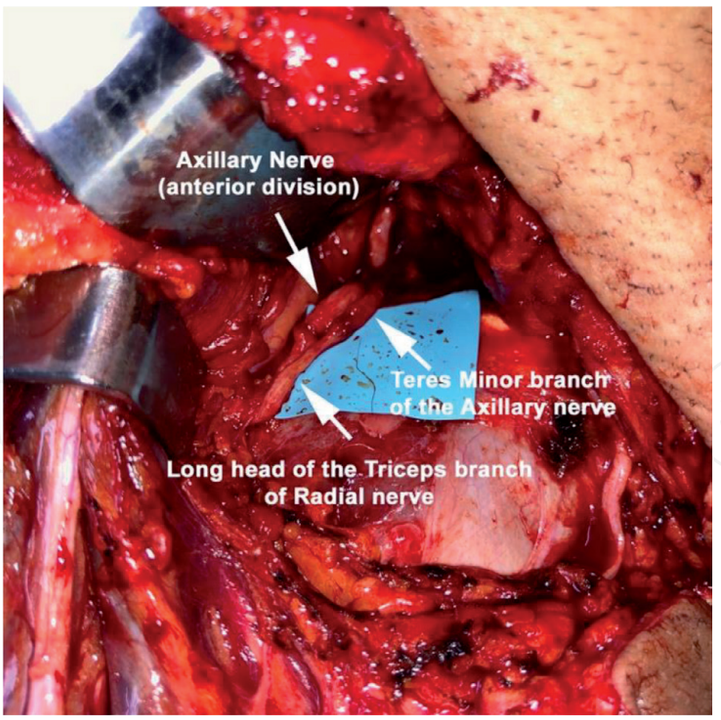

Figure 3.
Transfer of the rhomboid nerve to the suprascapular nerve with a posterior approach (right shoulder). This transfer can be performed without any tension. With this approach, the nerve is sutured close to the supraspinatus muscle, encouraging faster recovery (courtesy of Elsevier [10]).

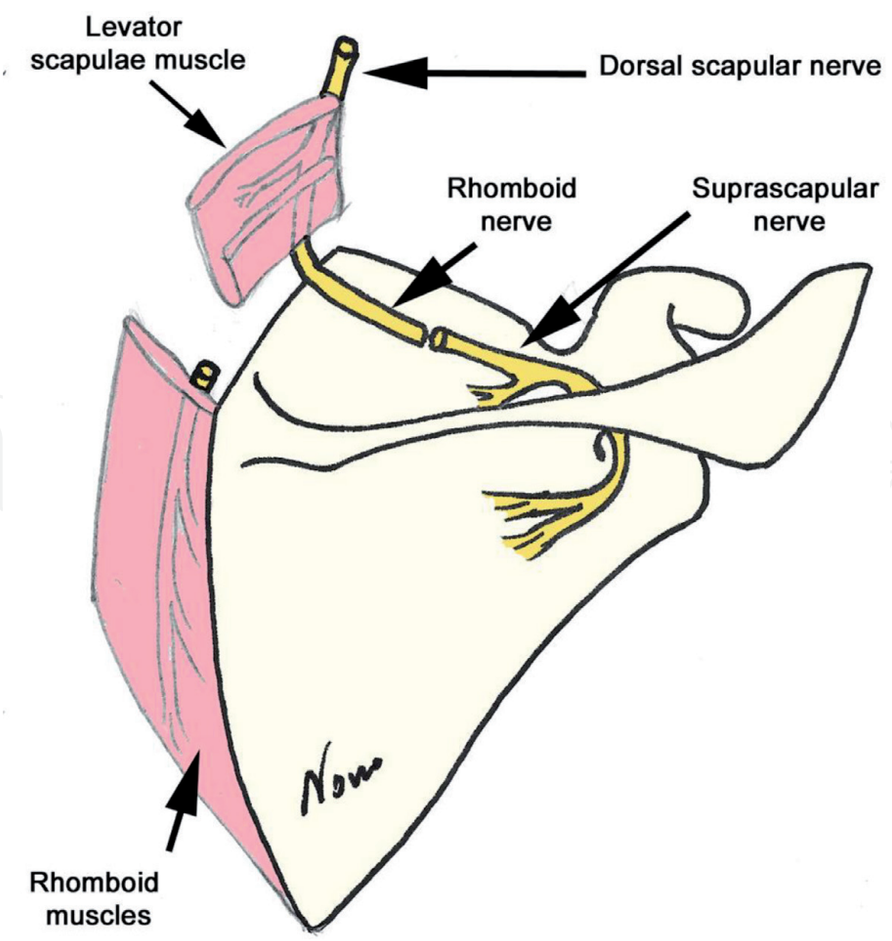

Figure 4.
Transfer of the radial nerve (long head of the triceps branch) to the anterior division of the axillary nerve and to teres minor branch by an axillary approach (right axilla).

triceps is easily identified because it is the first branch; electrostimulation clearly confirms with contraction of the long head of the triceps muscle. The axillary nerve is identified in the axillary fossa and the branch for the teres minor is isolated and separated from the axillary nerve. This branch is divided as distally as possible, then turned back toward the nerve of the long head of the triceps. The suture is generally made without tension (**Figure 4**).

The results for external rotation seem less satisfactory with this transfer than for the transfer of the spinal nerve. The teres minor is more of an accessory muscle for external rotation than the infraspinatus muscle [11]. The axon count showed that the number of fascicles in the branches of the radial nerve is less than the sum of fascicles in the axillary nerve and teres minor nerve. For this reason, some authors propose to use several branches of the radial nerve to optimize the number of fascicles transferred to the trunk of the axillary nerve and its branches (in particular the nerve of the teres minor) [12].

3. Other less used transfers

3.1 Transfer of a branch of the radial nerve to the infraspinatus muscle

This described transfer is anatomically possible. However, it does not seem to give satisfactory results for external rotation according to the authors [7] (**Table 1**). As a result, the authors do not recommend this transfer.

3.2 Transfer of a fascicle of the ulnar nerve to the teres minor nerve

This nerve transfer also only applies to cases where there are partial lesions of the brachial plexus and where a hand without palsy confirms the integrity of the ulnar nerve. One or two fascicles may have already been used to restore flexion of the elbow. Using additional ulnar fascicles could lead to a subsequent palsy with loss of grasp strength which would be very negative for the patient. The indication of this transfer should be considered with caution in the case of shoulder and elbow palsy.

3.3 Transfer of a fascicle of the C7 root to the suprascapular nerve

This transfer was proposed by Bertelli in 2004 using the contralateral C7 root [8] and by Yin et al. in 2012 using the ipsilateral C7 root [5]. The latter proposed to use a fascicle of C7 in order to restore the suprascapular nerve when the spinal nerve was not functional [5] (**Table 1**). The advantage of the ipsilateral transfer is that it can be carried out directly in the supraclavicular fossa and therefore is fully adapted if other procedures are carried out, especially a graft from the C5 or C6 roots if they are not avulsed. It should be noted that the damage to the spinal nerve during violent and prolonged trauma to the brachial plexus is generally associated with root avulsions, thus limiting this technique.

4. How to choose a transfer?

Prior to concluding that nerve transfer is indicated, the glenohumeral joint must obviously be assessed in order to rule out osteoarticular pathology that could mechanically limit the external rotation of the shoulder (joint malunion, gleno-humeral osteoarthritis, foreign bodies, etc). For this, imaging is necessary, such as simple standard x-rays of the shoulder or by performing arthrography of the glenohumeral joint (**Figure 5**).

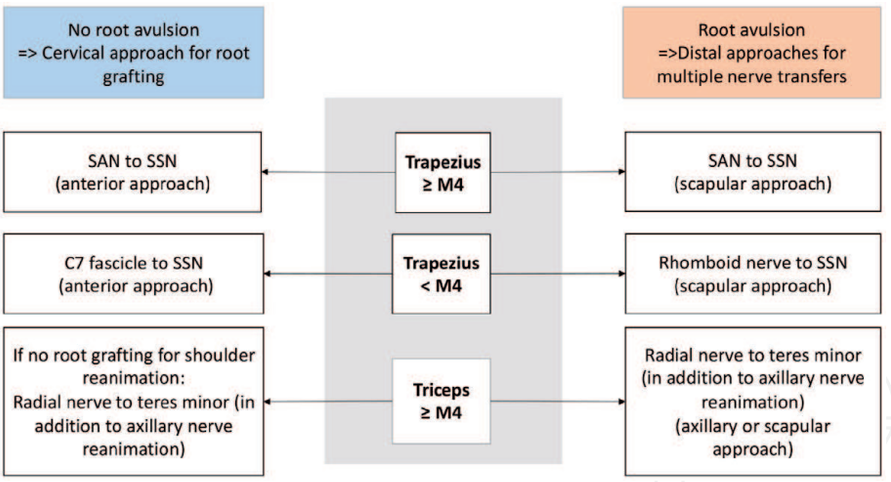

Figure 5.
Decision tree to choose the best nerve transfer for restoration of external rotation in adults with brachial plexus palsies. Trapezius and triceps muscles must be tested to assess the function of the spinal accessory nerve and the radial nerve, respectively. (SAN: Spinal accessory nerve; SSN: Suprascapular nerve.)

If a mechanical joint problem exists, it must be resolved before the nerve surgery if possible. In addition, glenohumeral arthrodesis can also be considered, allowing joint pathology and restoration of external rotation to be treated at the same time [13].

The choice of transfer depends primarily on the donor nerves available but also on the approaches used. If a cervical exploration of the plexus is chosen to carry out grafts (no root avulsions), in order to restore other functions, the use of the SAN (if the trapezius is functional) or of the fascicles from C7 root could be used with a direct suture on the SSN at its origin from the primary trunk, or by an extended approach at its entrance under the transverse coracoid ligament in order to improve results [1]. A distal transfer of a branch of the radial nerve (if the triceps is functional) to the teres minor could also be associated with this procedure in order to improve the results. If cervical exploration is not necessary (root avulsions), the use of the rhomboid nerve [9] (generally preserved even if the C5 root is avulsed), or of the SAN (if the trapezius is functional) by the posterior approach is preferred. In this context, a second distal transfer to the teres minor is rarely possible because if the C7 root is avulsed, the branches from the triceps are generally not functional, but in any case, the triceps must be tested because anatomical variations are possible.

5. Conclusion

The restoration of external rotation by nerve transfer is frequently possible because of numerous transfer possibilities. The use of one type of transfer or another depends on the reanimation strategy, on carrying out a cervical exploration and on other transfers used. A double transfer for external rotation can be generally also proposed.

The results, however, are often limited in terms of range-of-motion, even when the technique is carried out perfectly. Obviously, it is important to not forget the use of palliative muscle transfers, especially the transfer of the latissimus dorsi to the rotator cuff or the transfer of the lower part of the trapezius [14], if their innervation is preserved, or in the case of failure of the nerve surgery. Finally, for some, performing an arthrodesis on the shoulder will permit reestablishment of a superior external rotation compared with nerve transfers [13, 15].

Conflict of interest

"The authors declare no conflict of interest."

Author details

Jean-Noel Goubier[1*], Camille Echalier[2], Elodie Dubois[1] and Frédéric Teboul[1]

1 Nerve and Brachial Plexus Surgery Institute, Paris, France

2 Nollet Institute, Paris, France

*Address all correspondence to: jngoubier@gmail.com

References

[1] Bertelli JA, Ghizoni MF. Results of spinal accessory to suprascapular nerve transfer in 110 patients with complete palsy of the brachial plexus. J Neurosurg Spine. 2016;24(6):990-995.

[2] Bhandari PS, Deb P. Dorsal approach in transfer of the distal spinal accessory nerve into the suprascapular nerve: histomorphometric analysis and clinical results in 14 cases of upper brachial plexus injuries. J Hand Surg Am. 2011;36(7):1182-1190.

[3] Bertelli JA, Ghizoni MF. Refinements in the technique for repair of the accessory nerve. J Hand Surg Am. 2006;31(8):1401-1406.

[4] Zermeno-Rivera J, Gutierrez-Amavizca BE. Contralateral Spinal Accessory Nerve Transfer: A New Technique in Panavulsive Brachial Plexus Palsy. Indian J Surg. 2015;77(3):247-250.

[5] Yin HW, Jiang S, Xu WD, Xu L, Xu JG, Gu YD. Partial ipsilateral C7 transfer to the upper trunk for C5-C6 avulsion of the brachial plexus. Neurosurgery. 2012;70(5):1176-1181; discussion 81-2.

[6] Goubier JN, Echalier C, Dubois E, Teboul F. Transfer of the rhomboid nerve for restoration of shoulder external rotation in partial brachial plexus palsy. Injury. 2020;51 Suppl 4:S84-SS7.

[7] Tavares PL, Siqueira MG, Martins RS, Zaccariotto M, Foroni L, Heise CO, et al. Restoration of shoulder external rotation by means of the infraspinatus muscle reinnervation with a radial nerve branch transfer. Br J Neurosurg. 2020;34(5):552-558.

[8] Bertelli JA, Ghizoni MF. Contralateral motor rootlets and ipsilateral nerve transfers in brachial plexus reconstruction. J Neurosurg. 2004;101(5):770-778.

[9] Goubier JN, Teboul F. Transfer of the rhomboid nerve to the suprascapular nerve: An anatomical feasibility study. Chir Main. 2015;34(4):182-185.

[10] Goubier JN, Teboul F. Rhomboid nerve transfer to the suprascapular nerve for shoulder reanimation in brachial plexus palsy: A clinical report. Hand Surg Rehabil. 2016;35(5):363-366.

[11] Elhassan B, Bishop A, Shin A, Spinner R. Shoulder tendon transfer options for adult patients with brachial plexus injury. J Hand Surg Am. 2010;35(7):1211-1219.

[12] Khair MM, Schreiber JJ, Rosenblatt L, Byun DJ, Lee SK, Wolfe SW. Axon Counts Yield Multiple Options for Triceps Fascicular Nerve to Axillary Nerve Transfer. J Hand Surg Am. 2016;41(11):e405-ee10.

[13] Degeorge B, Lazerges C, Chammas PE, Coulet B, Lacombe F, Chammas M. Comparison of spinal accessory nerve transfer to supra-scapular nerve vs. shoulder arthrodesis in adults with brachial plexus injury. Orthop Traumatol Surg Res. 2019;105(8):1555-1561.

[14] Bertelli JA. Upper and lower trapezius muscle transfer to restore shoulder abduction and external rotation in longstanding upper type palsies of the brachial plexus in adults. Microsurgery. 2011;31(4): 263-267.

[15] Chammas M, Goubier JN, Coulet B, Reckendorf GM, Picot MC, Allieu Y. Glenohumeral arthrodesis in upper and total brachial plexus palsy. A comparison of functional results. J Bone Joint Surg Br. 2004;86(5):692-695.