Trakia Journal of Sciences, No 4, pp 329-335, 2021

Available online at:
http://www.uni-sz.bg

ISSN 1313-3551 (online) **doi:10.15547/tjs.2021.04.006**

Original Contribution

FUNCTIONAL RECOVERY AFTER NERVE TRANSFERS IN THE SHOULDER AREA FOR ADULT BRACHIAL PLEXUS INJURIES

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ABSTRACT

Purpose: Presentation of a physiotherapeutic program after nerve transfers in the shoulder area and follow-up of the effect of its application.

Material and methodology: The contingent is 15 men with a mean age of 37.1 years with adult brachial plexus injury and subsequent double nerve transfer in the shoulder area. The physiotherapeutic program before reinnervation, focuses on exercises with activation of the donor nerve. After the reinnervation active exercises are used, both with and without resistance, as well as exercises for distinguishing the old nerve function from the new one. Physiotherapeutic results were reported at the 6th and 12th postoperative months by goniometry and Medical Research Council Scale (MRCS).

Results: At the 12th postoperative month average active flexion 97.9º, average abduction 86.4º and average external rotation 32.1º were reported. The results of the MRCS of 12th postoperative month showed an average score of 3.6 for the shoulder abductors, an average of 3.1 for the shoulder flexors and an average of 2.9 for the external rotators.

Conclusion: An adequate physiotherapy program after nerve transfers provides the necessary reeducation of the donor's nerve. For a period of 12 postoperative months it is possible to achieve a good active range of motion and satisfactory muscle function in the shoulder area. This creates preconditions for the improvement of the combined movements in the shoulder, which are necessary for several activities of daily living.

Key words: postoperative physical therapy, n.accessorius, n.suprascapularis, n.phrenicus, n.axillaris, n.radialis

INTRODUCTION

The adult brachial plexus injuries are often associated with nerve root avulsions at various levels. This results in partial or complete loss of function in the upper limb, with no chance of spontaneous recovery. One of the surgical options to repair such injury is the nerve transfer (NT) or neurotiation. This is a procedure in which a healthy peripheral nerve (called a donor nerve) is transferred into a damaged one (called a recipient nerve) in order to restore its function. Among the priorities for recovery of the upper limb with neurotisation is the function of the shoulder joint (1). The presence of active abduction in a sufficient range of motion, as well as the good function of the scapular muscles are crucial for the full complex function of the entire upper limb. That's why the purpose of the present paper is to present appropriate physiothepeutic program after nerve transfers (NT) in the shoulder area in patients with adult brachial plexus injury and to follow-up the effect of its application.

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MATERIAL AND METHODOLOGY

In the period between 2015 and 2021 we worked with 15 men (average age of 37.1 years). All of them had an adult brachial plexus injury due to a motorcycle accident. All of them were operated at Sofiamed Hospital in the Clinic of Hand Surgery and Reconstructive Surgery. All patients underwent a double nerve transfer in the shoulder area. Nerve transfers are as follows: 15 n.accessorius to n.suprascapularis, 2 n.phrenicus to n.axillaris and 13 n.radialis to n.axillaris. The average time between injury and the first nerve transfer was 4.4 months, and the average time between the first and second nerve transfer was 2.5 months. The physiotherapy program was conducted within the first postoperative year. We have identified three phases of recovery after the NT - protection period, pre-reinnervation and post-reinnervation period. The protection period usually lasts between two and four weeks, depending on the specifics of the patient's case. For the beginning of the post-reinnervation period we consider the moment when twitching in the recipient muscles is detected. In our contingent, this is seen to happen on average at the 3.2th postoperative month. In the pre-reinnervation period, we mainly focused on passive abduction, flexion, and external rotation in the shoulder joint. Adhering to the theory of neuroplasticity (2, 3) and the accessible literature data on the rehabilitation after NT (4-8), we selected donor activating exercises depending on the type of the NT. For example, after n.phrenicus to n.axillaris nerve transfer, such a donor-activating exercise is deep breathing with simultaneous abduction in the shoulder. Initially, the movement is mostly passive **(Figure 1).** After reinnervation, the exercises for the recipient's muscles progress to active-assisted and active with and without resistance **(Figures 2, 3)**. After the good acquirement of the active abduction, flexion and external rotation, exercises for building new motor patterns and exercises for training daily living activities are included. Exercises to distinguish the old function of the nerve from the new are also added. **Figure 4** displays the active flexion of the shoulder with simultaneous scapular depression for distinguishing the new function of the accessory nerve after n.accessorius to n.suprascapularis nerve transfer. Various methods of electrical stimulation were also used. The dosage of these exercises is individual according to the therapeutic response of the patient. The results of the physiotherapeutic program were reported at 6th and 12th postoperative month (POM). The active range of motion (AROM) was measured by standard goniometry according to the SFTR methodics. The Medical Research Council Scale (MRCS) was used to report muscle strength.

Figure 1. Simultaneous passive shoulder abduction with deep breathing

Figure 2. Simultaneous breathing through a straw with active abduction of the shoulder

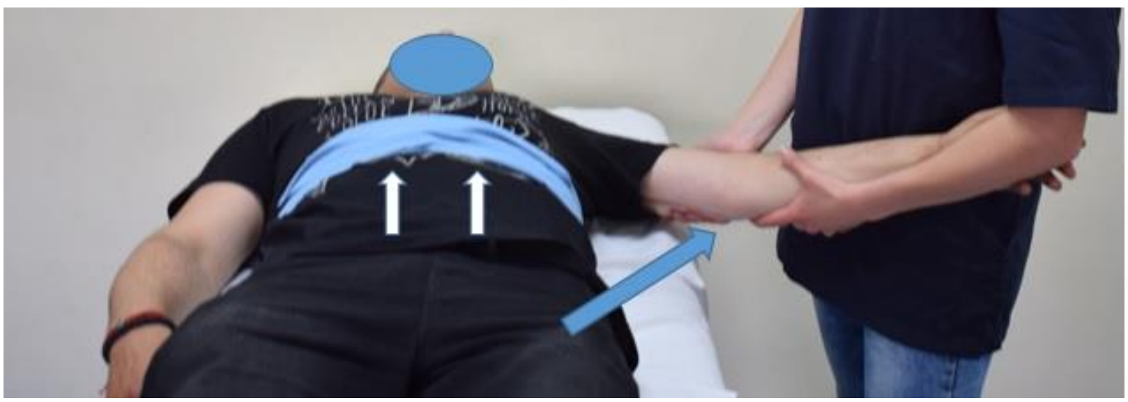

Figure 3. Simultaneous breathing against resistance of an elastic band with assisted abduction of the shoulder

Figure 4. Simultaneous shoulder active flexion with depression of the scapula

RESULTS

To process the results, Student's T-test for dependent variables was used. Preoperative active movements were absent due to the impaired innervation of the brachial plexus. Affected muscles had reduced to no muscle tone. Depending on the injury level and the presence of avulsion of nerve roots, this leads to weak or even absent active movements in the shoulder area. Postoperatively, we followed-up the most functionally important movements in the shoulder - flexion, abduction, and external rotation. They were also a priority in the selection of nerve transfer. The goniometry results of the active range of motion of these movements are presented in **Table 1**. On the 6th POM we have good average values of flexion (52.0º) and abduction (40.7º) in the operated shoulder joint. The external rotation, measured from a neutral position, has low average values in the specified period - 19.7º, but still provides good stability in the shoulder area. Shoulder stability is essential for creating relatively good synchrony between the scapula and the humerus which is extremely important for satisfactory active range of motion of upper extremity's elevation. On the 12th POM, a statistically significant improvement in all three measured movements was identified. The average value of flexion was 95.3º ($\alpha \leq 0.000$, P%=99.9%) and of abduction - 85.3º ($\alpha \leq 0.000$, P%=99.9%). The average external rotation from the neutral position has once again a relatively low value of 32.7º, but sufficient to maintain good stability in the glenohumeral joint.

Due to the nature of the brachial plexus injury, preoperative muscle function is missing or very weak. After the onset of the first muscle twitching, the donor activating exercises continue to progress in relation to the therapeutic response. This leads to a statistically significant improvement in muscle function. On the 6th POM abductors had an average MRCS score of 2.5, and on the 12th POM they reached a statistically significant improvement of 3.7 ($\alpha \leq 0.000$, P%=99.9%). Flexors (average MRCS score 2.4 of 6th POM and 3.1 of 12th POM, $\alpha \leq 0.001$, P%=99.9%) and external rotators (average MRCS score 2.0 of 6th POM and 2.8 of 12th POM, $\alpha \leq 0.000$, P%=99.9% also reported positive changes. **(Table 2).**

Table 1. *Results of the shoulder's active range of motion measurement*

№	AROM in shoulder	6th POM		12th POM		d	t	α	P%
		X1 cp	S1	X2 cp	S2				
1.	Flexion	52.0º	26.78	95.3º	53.83	43.3	4.914	0.000	99.9%
2.	Abduction	40.7º	21.54	85.3º	50.37	44.7	4.518	0.000	99.9%
3.	R ext (neutral position)	19.7º	13.29	32.7º	17.10	13.0	4.964	0.000	99.9%

Table 2*. Results of Medical Research Council Scale for the shoulder muscles*

№	MRC Scale	6th POM		12th POM		d	t	α	P%
		X1 cp	S1	X2 cp	S2				
1.	Abductors	2.5	.74	3.7	0.49	1.13	8.500	0.000	99.9
2.	Flexors	2.4	.91	3.1	1.19	0.73	4.036	0.001	99.9
3.	External rotators	2.0	1.0	2.8	0.77	0.8	7.483	0.000	99.9

DISCUSSION

Nerve transfers of the n.accessorius to the n.suprascapularis and n.radialis (a branch of the long head of the m.triceps brachii) to the n.axillaris are widely used in the surgical treatment of late brachial plexus injuries. The various collective authorships (9-18) unanimously agree that these nerve transfers give good results for the active shoulder abduction **(Table 3).**

After n.accessorius to n.suprascapularis and n.radialis (a branch from the long head of m.triceps brachii) to n.axillaris nerve transfers, whether single or double, muscle function of the abductors is relatively well-restored - in most cases between M3 and M4 assessments according to MRCS (9, 12- 15, 17-18). Similar results were achieved by M. Kateva et al (19) with double nerve transfer n.accessorius to n. suprascapularis and n.radialis (branch from the medial head of m.triceps brachii) to n.axillaris. Their 5 patients reached M3-M4 for shoulder abductors. The same collective authorship (20) followed-up 36 patients with nerve transfer n.accessorius to n.suprascapularis for an average of 2 postoperative years. An average active abduction of 45º and scores between M3 and M4 of the MRCS for the shoulder abductors were achieved.

Unfortunately, these nerve transfers do not have the desired effect in terms of active external rotation. Various authors report external rotation between 66º and 93º, measured by complete internal rotation. The muscular function of the external rotators hardly reaches M3 score of the MRCS, even in a small number of subjects (9, 18). However, this nerve transfer creates good conditions for the development of satisfactory shoulder stability (10, 18, 21-24). Our results of AROM and MRCS in this relatively short follow-up period are close to those indicated in the corresponding literature. We tend to associate them with the right choice of the donor nerve, the excellent operative technique, and the correctly selected therapeutic exercises for each of the recovery periods.

Table 3. *Literature data of various collective authorships about the active abduction of the shoulder*

№	Authors	Contingent/ Type of the nerve transfer(s)	Average postoperative follow-up	Average postoperative shoulder active abduction
1.	Bertelli J. et al. (9) (2004)	10 patients with n.accessorius to n.suprascapularis and n.radialis (branch from the long head of m.triceps brachii) to n.axillaris nerve transfers	24 months	95º
2.	Bertelli J. et al. (10)	30 patients with direct neurotisation n.accessorius to n.suprascapularis	29,1 months	105º
3.	Bertelli J. et al. (11)	110 patients with n.accessorius to n.suprascapularis nerve transfer	40 months	58.5º
4.	Leechavengvongs, S. et al. (12)	7 patients with n n.accessorius to n.suprascapularis and n.radialis (branch from the long head of m.triceps brachii) to n.axillaris nerve transfers	20 months	124º
5.	Desai, M. et al. (13)	22 patients с n.radialis (branch from the long head of m.triceps brachii) to n.axillaris nerve transfer	22 months	114º
6.	Emamhadi, M. et al. (14)	22 patients с n.accessorius to n.suprascapularis nerve transfer	21.7 months	55.55º
7.	Bhandari P. et al (15)	20 patients с n.accessorius to n.suprascapularis and n.radialis (branch from the long head of m.triceps brachii) to n.axillaris nerve transfers	22.3 moths	95º
8.	Socolovsky, M. et al. (16)	18 patients с n.accessorius to n.suprascapularis nerve transfer	24 months	49.7º
9	Kostas-Angantis, I. et al. (17)	11 patients с n.accessorius to n.suprascapularis and n.radialis (branch from the long head of m.triceps brachii) to n.axillaris nerve transfers	At least 18 months	112.2º
10	Venkatramani H. et al. (18)	15 patients с n.accessorius to n.suprascapularis nerve transfer	15 months	66º

N. phrenicus is used as a donor nerve for neurotisation in case there is no other suitable donor. Sinis et al. (22) described clinical case with transfer of n.phrenicus to n.axillaris in a 39-year-old patient after a motorcycle accident. He underwent surgery on the 6th month after the injury. The authors report there was a satisfactory shoulder stability gained and 40º active abduction in the shoulder on the 18th postoperative month. In Bulgarian practice, n.phrenicus is harvested laparoscopically along its entire length. This shortens the time for reinnervation of the recipient muscles by 7-12 postoperative months. The use of n. phrenicus as a donor nerve does not lead to permanent disturbances in the respiratory capacity and pulmonary function of the patients (25). Part of the contingent involved and described in this article has, undergone this precise kind of nerve transfer with donor n.phrenicus along its entire length.

ACKNOWLEDGEMENTS

The author expresses her sincere gratitude and deep appreciation for working together with the team of Prof. Dr. Margarita Kateva, MD – Chief of Clinic of Hand Surgery and Reconstructive Surgery at Sofiamed University Hospital, Sofia, Bulgaria; and physiotherapist Georgi Petrov, MSc from the Physiotherapy office "Handrehab Consult", Sofia, Bulgaria.

CONCLUSION

Physiotherapy is an integral part of the overall rehabilitation of patients with nerve transfers in the shoulder area. Methodologically correct application in a one-year postoperative period reports a statistically significant increase in the active range of motion and the muscle strength of the shoulder. This determines an improvement of the important functional movements performed with the upper limb, which are necessary for a number of the activities of daily living.

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