Egypt, J. Plast. Reconstr. Surg., Vol. 43, No. 3, October: 509-515, 2019

Neurotization for Elbow Flexion Restoration after Brachial Plexus Injury

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ABSTRACT

Background: Restoration of elbow flexion after brachial plexus injury has the first priority in adults. Nerve transfers (neurotization) involves taking nerves with less important functions or branches of a nerve that perform redundant functions to restore important function in a more crucial nerve that has been severely damaged. There are many described neurotization methods for elbow flexion restoration like Oberlin method, Double Fascicular Transfer (DFT) and Intercostal Nerves (ICN) transfer. The aim of this study was to evaluate different methods of nerve transfer for restoration of elbow flexion after brachial plexus injury.

Patients and Methods: 21traumatic BPI were included in this study (19 unilateral BPI and 1 bilateral BPI). 4 patients were operated by Oberlin method, 5 by DFT and 12 by ICN transfer.

Results: 3 primary procedures were used. Oberlin method in 4 cases (19.0%) 3 cases (75%) give results M3 or more. DFT method in 5 cases (23.8%) all of them give results M3 or more. ICN transfer in 12 cases (57.1%) 9 cases (75%) give results M3 or more.

Conclusion: In upper BPI, DFT is the first option due to effectiveness without noticeable donor functional affection and Oberlin method is the 2nd option if median nerve has functional deficit or not well recovered or has been used in another transfer as in (c5, c6 and c7) cases. Three ICNs transfer to musculocutaneous nerve without nerve graft in total BPI is advisable due to effectiveness and least morbidity.

Key Words: *Neurotization – Elbow – Flexion restoration – Brachial plexus injury.*

INTRODUCTION

Restoration of elbow flexion after brachial plexus injury has the first priority in adults. Nerve transfers (neurotization) involves taking nerves with less important functions or branches of a nerve that perform redundant functions to restore important function in a more crucial nerve that has been severely damaged.

Traumatic brachial plexus palsy is caused by root avulsion or traction across long segments of the trunks, divisions or cords or segmental in nature needs long nerve graft >10cm or delayed interference with fear of motor endplate denervation. Nerve transfer (neurotization) employs redirection of an intact motor nerve from one muscle to the distal undamaged portion of a nerve from another, effectively bypassing the injured segment of nerve **[1]**.

Nerve transfer to restore elbow flexion either by intraplexal or extraplexal sources. In 1988, Narakas described his extensive experience using intercostal nerves as donor nerves for brachial plexus neurotization **[2]**.

Christophe Oberlin described transfer of one or more ulnar nerve fascicles to the motor branch(es) of the biceps muscle as an intraplexal source **[1,3]**.

Mackinnon reported direct transfer of motor fascicles from both ulnar and median nerves to the biceps and brachialis branches of the musculocutaneous nerve **[1,4]**. The aim of this study was to evaluate different methods of nerve transfer for restoration of elbow flexion after brachial plexus injury.

PATIENTS AND METHODS

21 traumatic BPI were included in this study in 20 patients (19 unilateral BPI and 1 bilateral BPI), 2 females and 18 males. 12 total BPI and 9 upper BPI. 5 BPI by motor car accident, 15 BPI by motor bike accident and 1 BPI fall from height.

This study has been conducted at Al-Azhar University Hospitals, Cairo, Egypt and Zagazig University Hospitals, Zagazig, Egypt from April 2015 to November 2018.

Pre-operative diagnosis including history, examination, X-ray, electrodiagnostic studies, CT-myelography or MRI. Surgery was preceded by exploration of the plexus through supraclavicular incision in 18 cases and direct neurotization in 3 cases without exploration.

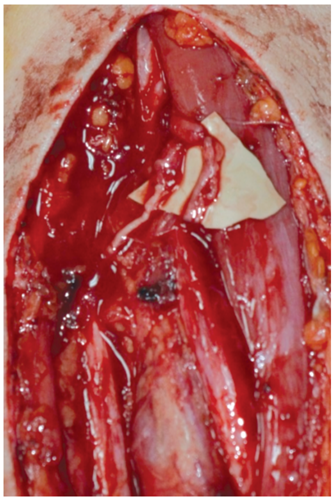
3 primary procedures were used. Oberlin method in 4 cases, DFT method in 5 and ICN transfer in 12 cases.

Double Fascicular Transfer (DFT): Mackinnon reported direct transfer of motor fascicles from both ulnar and median nerves to the biceps and brachialis branches of the musculocutaneous nerve **[1,4]**. It is indicated if the patient has upper BPI (c5, c6 or c5, c6, c7) with intact or well recovered (c8, t1). The median and ulnar nerves are identified as they course medial to the MCN. FCU fascicles from ulnar nerve is used to neurotize biceps muscle and FDS fascicles from median nerveis used to neurotize brachialis muscle. Fig. (1).

Oberlin method: Christophe Oberlin described transfer of one or more ulnar nerve fascicles to the motor branch(s) of the biceps muscle as an intraplexal source **[1,3]**. Transfer from ulnar nerve only to biceps in case of incomplete recovery of median nerve or if the median nerve as a donor will be used for another transfer rather than elbow flexion restoration like median nerve fascicular transfer to posterior interosseuss and ECR fascicles of the radial nerve to restore wrist extension.

Intercostal nerve transfer: In case of total BPI root avulsion, extraplexal source has to be used. Intercostal nerves are usually the best and the safest with the lowest morbidity donors for transfer for elbow flexion restoration. An arch-shaped incision across the chest, along the anterior axillary line, was made. The ICNs of the third to 5th ribs or even the seventh rib were identified and dissected along their course. The dissection started very medially to achieve good length to do direct neurotization for MCN without any graft. The ICNs were then passed from the chest incision to the medial arm incision where the musculocutaneous nerve was exposed and sectioned at the common trunk, proximal to the emergence of the branches to the biceps brachii muscle. Finally, the ICN was sutured to the musculocutaneous nerve (centered at the division to the branch of the biceps brachii muscle) with a 9-0 nylon stitch with fibrin glue directly without any tension while the shoulder was abducted to 90 degrees. Usually three ICN transfers were performed. Fig. (2).

Fig. (1): Double fascicular transfer to biceps and brachialis.



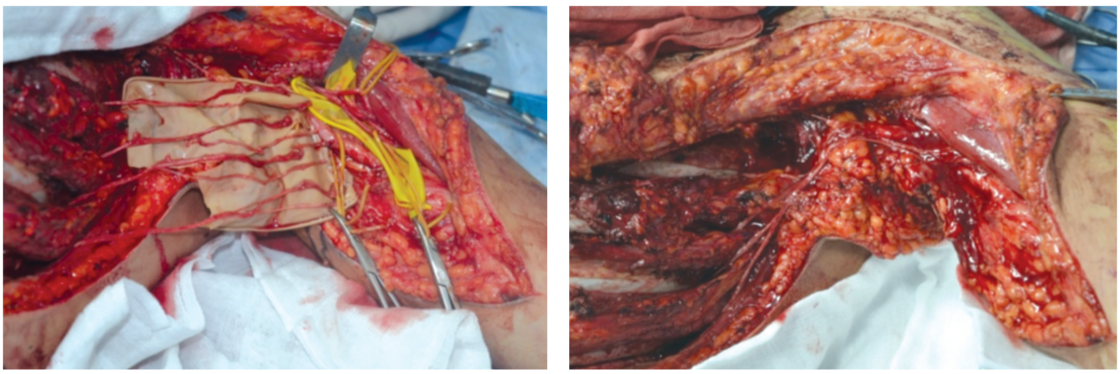


Fig. (2): Intercostal nerve transfer.

RESULTS

21 traumatic BPI were included in this study (19 unilateral BPI and 1 bilateral BPI).

Concerning patients demographics showed 20 patients two of them are females (10%) and 18 male (90%). Affected side was right in 7 cases (35%) and left in 12 cases (60%) and one bilateral case (5%). The age ranged from 16 to 60 years old with mean age 29.5 years old. The mean duration before operation was 6.3 months. The pre-operative diagnosis of the affected side was upper BPI in 9 affected side (42.9%) and total BPI in 11 affected sides (57.1%) (Table 2).

Supraclavicular exploration was done in 17 cases and direct neurotization in 3 cases. 3 primary procedures were used in this study. Oberlin method in 4 limbs (19.0%), DFT method in 5 limbs (23.8%) and ICN transfer in 12 limbs (57.1%).

The mean of operation duration for ICN (4.4) hours neurotization method; was the highest mean followed by DFT (3.6) hours then Oberlin (3.0) hours. That difference was statistically significant. There were statistically significant differences between {ICN Vs. DFT} & {ICN Vs. oberlin}; while there was no statistically significant difference between {DFT Vs. oberlin}. The mean difference of duration of operation for ICN was >Oberlin and DFT by 1.21 & 0.86 respectively (Table 1, Fig. 3).

17 case (80%) showed results of post-operative MRC for elbow flexion M3 or more. There were no statistically significant differences between the different methods of neurotization regards post-operative. Oberlin method was used in 4 limbs (19.0%) 3 limbs (75%) give results M3 or more. Also DFT method in 5 limbs (23.8%) all of them give results M3 or more. Lastly, ICN transfer was used in 12 limbs (57.1%) 9 limbs (75%) give results M3 or more (Table 3).

Indirect correlation between post-operative MRC and duration before operation. While; no correlation between post-operative MRC and age (Table 4, Figs. 5,6).

Table (1): Comparison between methods of neurotization regards time of operation.

Time of operation (hours)	N	Mean	SD	Median	Range	F	*p*-value	Sig.
ICN [a]	12	4.4	0.6	4.3	3.5-5	7.91	0.003	HS
Oberlin [b]	4	3.0	0	3.0	3-3			
DFT [c,b]	5	3.6	0.9	3.0	3-5			

One-Way ANOVA.

Table (2): Characteristic data of the studied cases.

No	Age	Sex	Side	Pre-op. MRC	Method of neurotization	Duration before operation (m)	Operation time (h)	Post-op. MRC	Follow-up duration (m)
1	21	M	LT	0	ICN	5m	4	4	18
2	20	M	RT	0	Oberlin	4	3	5	12
3	26	M	LT	0	DFT	6	5	4	10
4	18	M	LT	0	ICN	7	5	2	18
5	48	M	RT	0	ICN	9	4:30	3	18
6	60	M	RT	0	ICN	6	5	2	30
7	60	M	LT	0	Oberlin	7	3	3	30
8	39	F	LT	1	DFT	4	4	4	18
9	16	M	LT	0	ICN	7	5	4	18
10	28	M	LT	0	ICN	10	5	3	18
11	44	F	LT	0	Oberlin	7	3	5	30
12	25	M	RT	0	ICN	7	3:30	3	6
13	21	M	RT	0	ICN	6	5	3	18
14	34	M	RT	0	ICN	10	4	1	7
15	24	M	LT	0	DFT	4	3	4	18
16	18	M	LT	0	ICN	5	4	4	30
17	36	M	LT	0	Oberlin	6	3	2	7
18	18	M	LT	0	ICN	5	3:30	5	30
19	25	M	RT	0	ICN	4	4	4	30
20	20	M	RT	0	DFT	6	3	3	14
21	18	M	LT	0	DFT	7	3	5	18

Table (3): Comparison between methods of neurotization regards post-operative MRC.

Methods of neurotization	ICN (n=12)	Oberlin (n=4)	DFT (n=5)	Total (n=21)	χ^2	*p*-value	Sig.
<3	3 (25%)	1 (25%)	0	4 (19%)	1.46	0.596	NS
≥3	9 (75%)	3 (75%)	5 (100%)	17 (81%)			

Fisher's Exact Chi-Square Test.

Table (4): Correlation between post-operative MRC and age, duration before operation.

	Age	Duration before operation	Follow-up
Post MRC:			
r	–0.35	–0.52	0.34
p-value	0.116	0.016	0.126
Sig.	NS	S	NS

Pearson correlation.

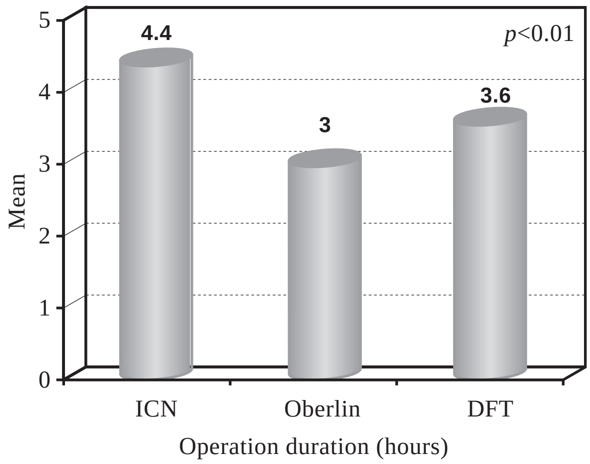


Fig. (3): Bar chart representing comparison between methods of neurotization regards duration of operation.

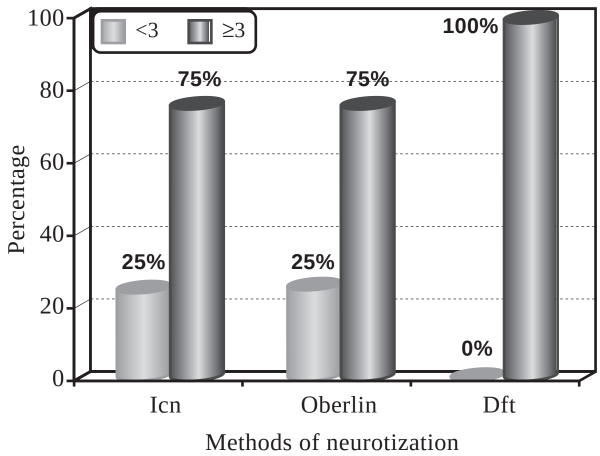


Fig. (4): Bar chart representing comparison between methods of neurotization regards post-operative MRC.

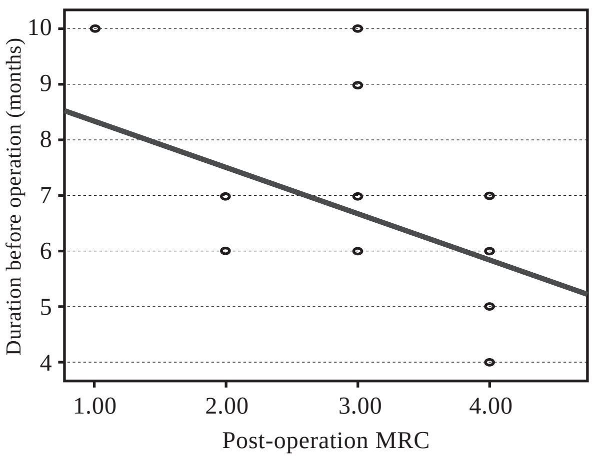


Fig. (5): Correlation between post MRC and duration before operation.

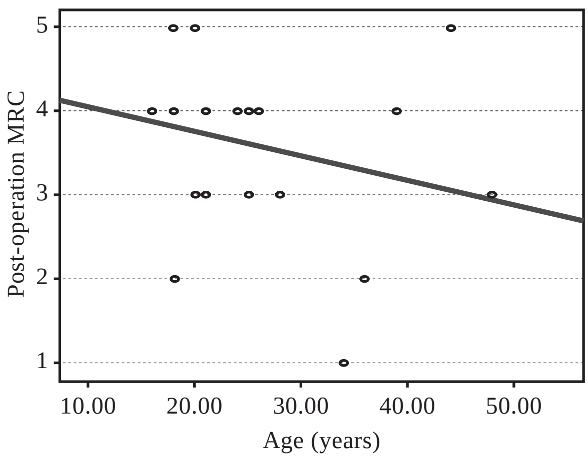


Fig. (6): Correlation between post MRC and age.

Fig. (7): Result after oberlin method in the right side. Case no. (2).

Fig. (8): Result after DFT method in the left side. Case no. (8).

Fig. (9): Result after intercostal nerve transfer for the right side. Case no. (19).

Fig. (10): Result after ICN method in the right side. Case no. (13).

DISCUSSION

Restoration of elbow flexion is the first priority in upper BPI Reconstruction **[5]**. When primary nerve repair is not possible, muscle and tendon transfers was the options which are limited by donor site morbidity **[6]**.

The use of nerve grafts involves less dissection and avoids scarring in the muscle bed; however, grafting can result in a failure to provide regenerating axons to the denervated motor endplate within the critical window of 1 year after injury **[6]**. The central principle of nerve transfers is the conversion of a high nerve injury to a low injury that is closer to the target end organ **[7]** with reinnervation of the motor endplate before the onset of severe degeneration and fibrosis **[6,8]**, shorter operative times with exclusion of the sensory environment **[9,10]** and the utilization of expendable donor fascicles that cause no functional deficit in the donor nerve distribution **[4]**. Nerve transfer procedures markedly improved the functional outcomes obtained in comparison with traditional graft and repair techniques **[6]**. Many nerve transfer procedures have been proposed for the restoration of MCN function after upper brachial plexus injury.

Three procedures were used in our patients (4 limbs (19.0%) Oberlin, 5 limbs (23.8%) DFT and 12 limbs (57.1%) ICN).

The transfer of an expendable FCU fascicle (Oberlin method) [3,12] to the biceps nerve represented a significant step forward in the evolution of nerve transfers for upper brachial plexus injuries because it offered an easily accessible donor to the biceps muscle. By reinnervating the biceps, the expendable ulnar fascicular transfer restored Grade M3 or M4 strength in 24 of 32 patients [12] however, [10] of these patients required secondary Steindler flexorplasty to achieve satisfactory elbow flexion strength [11]. In this study, Oberlin procedure was used in 4 limbs (19.0%) and results were M3 or more in 3 limbs (75%). One of these 3 cases achieved M5 result.

The transfer of expendable fascicles of the median nerve to the biceps muscle has been described [12-14]. In June 2001, the DFT was performed to reinnervate both the biceps and brachialis muscles using expendable motor fascicles from the ulnar and median nerves [4]. Results in a series of 6 patients were reported and followed-up for a mean period of 20.5 months. At the final evaluation, all patients had recovered Grade M4-4+ elbow flexion strength [4]. In a study by Livernaux et al., [15] Grade M4 elbow flexion strength was restored in 10 of 10 patients at a mean follow-up of 15 months. Goubier and Teboul documented the restoration of M4 elbow flexion strength to all 5 patients in their study at a mean follow-up of 14 months [16]. A study done on 41 patients 16 of them were treated by Oberlin method and 25 patients were treated by DFT and they find significant deference in post-operative MRC in favor to DFT [17]. In this study, DFT was used in 5 limbs (23.8%) and (100%) achieved results M3 or more and one of them achieved M5 result. DFT method was used in upper BPI except if median nerve was used for another transfer as in (c5, c6 and c7) cases. Also, this technique should be avoided if there is function deficit in median nerve distribution.

ICN is one of the most important donor nerves for total BPI. ICN transfer to the musculocutaneous nerve was first attempted by Seddon for a patient with complete root avulsion [18]. Tsuyama et al., and Nagano et al., developed a modified method of this procedure using direct ICN transfer without nerve grafts and obtained good results [19,20]. Nagano reported that 97 (87%) of 112 patients could voluntarily flex the elbow joint against gravity following two ICN transfers [20]. According to other reports, successful results of elbow flexion to MRC grade M3 with two ICN transfers were achieved in between 59% of cases [22,23]. Chuang et al., and Malessy et al., recommended using three ICNs to recover elbow flexion. They reported useful elbow flexion rates of 73% (27/37) and 64% (16/25) [22,24]. Waikakul et al., and Tonkin et al., reported similar outcomes utilizing three ICNs [25,26]. Berger and Becker reported good result M3 or M4 using three or four ICNs [27]. In this study, 3 ICNs transfer without interposition nerve graft was used in 12 limbs (57.1%) of cases and achieved function of M3 or more in 9 limbs (75%). This technique is considered as the method of choice for elbow flexion restoration in total brachial plexus injury cases.

Conclusion:

In upper BPI, DFT is the first option due to effectiveness without noticeable donor functional affection, Oberlin method is the 2nd option if median nerve has functional deficit or not well recovered or has been used in another transfer as in (c5, c6 and c7) cases. Three ICNs transfer to musculocutaneous nerve without nerve graft in total BPI is advisable due to effectiveness and least morbidity.

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