

Early Post-Operative Results after Repair of Traumatic Brachial Plexus Palsy

Travmatik Brakiyal Pleksus Palsisi Tamirinden Sonra Erken Postoperatif Sonuçlar

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ABSTRACT

AIM: Treatment options for traumatic brachial plexus injuries include nerve grafting, or neurotization. The type of lesion and the reconstructive procedures affect functional results and postoperative pain relief.

MATERIAL and METHODS: A total number of twenty five patients suffering from post-traumatic brachial plexus injury were included in the study. The patients underwent exploration and primary repair of the affected plexus, based on case by case policy.

RESULTS: Spinal accessory nerve transfer to suprascapular nerve procedure regained 78.95% of functional muscle power, 10.50% of non functional muscle power and only 10.5 % of non innervated muscle. The Oberlin procedure regained 83.33% with elbow flexion muscle power, 16.67% with non functional muscle power. Intercostal nerve transfer to musculocutaneous nerve regained 62.5% with functional muscle power, 25% with non functional muscle power and only 12.5 % with non innervated muscle. The shoulder, elbow and wrist extension functions were significantly improved early post-operatively. In addition, the post-operative improvement of shoulder, elbow and wrist extension functions had significant negative correlations with the pre-operative elapsed time, and accompanied by a significant positive correlation with post-operative follow up period.

CONCLUSION: Early intervention for traumatic brachial plexus palsy is recommended to get good results with pain relief.

KEYWORDS: Brachial plexus, Traumatic, Neurotization

ÖZ

AMAÇ: Travmatik brakiyal pleksus yaralanmaları için tedavi seçenekleri arasında sinir grefti veya nörotizasyon vardır. Lezyon tipi ve rekonstrüktif işlemler işlevsel sonuçları ve postoperatif ağrı kesilmesini etkiler.

YÖNTEM ve GEREÇLER: Bu çalışmaya posttravmatik brakiyal pleksus yaralanması olan toplam yirmi beş hasta dahil edildi. Her vakanın durumuna göre karar verilerek hastalarda etkilenen pleksusta eksplorasyon ve primer tamir yapıldı.

BULGULAR: Supraskapular sinire spinal aksesuar sinir transferi %78,95 işlevsel kas gücü, %10,50 işlevsel olmayan kas gücü ve sadece %10,5 innerve olmayan kas kazandırdı. Oberlin işlemi %83,33 dirsek fleksiyonu kas gücü ve %16,67 işlevsel olmayan kas gücü kazandırdı. Müskülökütanöz sinire interkostal sinir transferi %62,5 işlevsel kas gücü, %25 işlevsel olmayan kas gücü ve sadece %12,55 innerve olmayan kas kazandırdı. Omuz, dirsek ve bilek ekstansiyon işlevleri postoperatif erken dönemde önemli ölçüde düzeldi. Ayrıca, omuz, dirsek ve bilek ekstansiyon işlevlerinin postoperatif düzelmesinin preoperatif geçen süreyle önemli bir negatif korelasyonu bulundu ve postoperatif takip dönemiyle önemli bir pozitif korelasyonu vardı.

SONUÇ: Travmatik brakiyal pleksus palsisinde ağrı giderilmesiyle birlikte iyi sonuçlar alınması için erken girişim önerilir.

ANAHTAR SÖZCÜKLER: Brakiyal pleksus, Travmatik, Nörotizasyon

INTRODUCTION

The improved modern-day outcome of brachial plexus reconstruction, even with severe degrees of palsies involving root avulsions, is a result of many factors: first, the advent of microsurgical techniques, second, better understanding of the nature of brachial plexus injuries and third, the extensive research on surgical techniques (41).

The application of microsurgical techniques and the establishment of the principle of tension free repair in peripheral nerve surgery, brought several new techniques for

brachial plexus reconstruction, especially in supraclavicular lesions with multiple avulsions (40). A variety of extraplexus donors has been introduced to neurotize selected muscles in order to achieve essential function in the shoulder, elbow and hand (36).

In 1961 Yeoman and Seddon (45) advocated neurotization of the musculocutaneous nerve with intercostal nerve transfer. Then other nerve transfers were used such as the contralateral lateral pectoral nerve, spinal accessory nerve, the hypoglossal nerve, phrenic nerve, contralateral C7, and selective ulnar

nerve (3, 11,19,23,24). The best outcome of neurotization can be expected in short denervation times and in the presence of proximal healthy roots (4). Moreover, neurotizations using unavulsed roots are superior to utilization of extraplexus donors (7).

Surgery is indicated in closed lesions leading to traumatic brachial plexus palsy, with no improvement after 3 months. Surgery consists of the repair of affected nerves if possible, and if the nerves have been avulsed peripheral neuritization is indicated (14,22).

Recently, indications for peripheral neuritization have been expanded to high-level nerve injuries with extensive gap for grafting and delayed nerve repairs (44), as well as to major bony or vascular injuries in the region of direct repair and previously failed proximal nerve repair (1). The main advantage of this procedure over classical nerve grafting is a conversion of proximal high-level injury to a low-level (44).

The aim of the present study was to assess the early results and prognostic values of the surgical treatments of traumatic brachial plexus on both functions and associated pain.

PATIENTS and METHODS

From March 2008 to July 2011, a total number of twenty five patients suffering from post traumatic brachial plexus injury

were presented in general surgery department, plastic surgery unit in Zagazig University Hospital. This study emphasized the evaluation of shoulder, elbow, and wrist extension because the early postoperative results occurred in these parts. Some of the patients (6 patients) had presented clinically with zero shoulder function and zero elbow functions (upper brachial plexus palsy; C5 and C6), and others had clinically presented with zero shoulder function, zero elbow functions and no wrist extension (19 patients: 14 of them had total brachial plexus palsy and 5 of them had upper brachial plexus palsy; C5, 6 and C7) (Table I).

Patient age ranged from 10 to 51 yeas with main value of (\pm SD) of 25 ± 13.26 (20 males and 5 females). The time elapsed before surgery was ranged from 3 to 24 months with main value of 6.32 ± 4.22 months.

Patients provided consent after explanation of the surgical techniques and the expected results. The study design was approved by the research ethics committee of the faculty of medicine, Zagazig University.

Detailed neurological and functional evaluation including muscular strength, and pain were done (Figure 13 A-C). Muscular strength was recorded according to British Medical Research Council (BMRC) grading (10, 33,45) (Table II).

Table I: Traumatic Brachial Plexus Lesions and the Procedures Used for the Twenty Five Patients

Cases	Lesion	Procedure
3	Rupture of C5-6 roots.	Spinal accessory transfer to suprascapular nerve. Repair of upper trunk from C5 & middle trunk from C6.
2	Rupture of C5-6 roots.	Spinal accessory transfer to suprascapular nerve. Repair of upper trunk from C5 & middle trunk from C6. Motor fascicle from radial nerve to axillary nerve
2	Rupture of C5-6 roots & avulsion of C 7.	Spinal accessory transfer to suprascapular nerve, Oberlin (motor fascicle from ulnar nerve to musculocutaneous nerve).
2	Rupture of C5-6 roots.	Spinal accessory transfer to suprascapular nerve, Oberlin procedure. Repair of upper trunk from C5 & middle trunk from C6.
2	Rupture of C5-6 roots	Plexo-plexal repair using cable nerve grafts.
2	Rupture of C5-6 roots.	Oberlin procedure.
2	Rupture of C5- roots. C6-7-8, T1 avulsion,	Spinal accessory transfer to suprascapular nerve, intercostal nerves transfer to musculocutaneous nerve. Repair of lower trunk from C5.
2	Rupture of all cords.	Interposition Sural grafts, subclavein artery & vein grafting,
2	Avulsion of all roots	Spinal accessory transfer to suprascapular nerve, intercostal nerves transfer to musculocutaneous nerve.
2	Rupture of C5-6 roots avulsion of C 7-8 & T 1	Spinal accessory transfer to suprascapular nerve, intercostal nerves transfer to musculocutaneous nerve, Repair of middel trunk from C5 & lower trunk from C6.
2	Rupture of C5-6 roots avulsion of C 7-8 & T 1	Spinal accessory transfer to suprascapular nerve, Repair of upper trunk from C5 & middle trunk from C6.
2	Rupture of C5 root avulsion of C 6-8 & T 1	Spinal accessory to suprascapular nerve, intercostal nerves to musculocutaneous nerve, cross C7 to lower trunk.

Table II: BMRC Grading of Muscle Power

Grade	Muscle power	Function
0	No contraction	Non innervated
1	Palpable but not visible contraction	Non functional
2	Movement when gravity has been excluded	Non functional
3	Movement against gravity	functional
4	Movement against resistance	functional
5	Normal muscle power	functional

Pain was described in terms of its time of onset, site, radiation, and relief with medication (12); Degree 0 indicated no pain, degree 1 indicated intermittent pain that related usually to the weather or to the patient's emotional state, degree 2 denoted severe pain, and degree 3 expressed intolerable pain that was sufficient to awaken the patient from sleep and could not be relieved by major analgesics (5).

All patients were operated by exploration and repair of the brachial plexus. Different types of reconstruction were conducted, the choice of procedure being made on a case by-case basis. The post-operative follow up periods with physiotherapy ranged from 6 to 36 months with a mean value of 18.88 ± 8.22 months.

Surgery was executed under general anesthesia in supine position and without usage of muscle relaxants. A zigzag skin incision was used in some of the cases: a supraclavicular incision and an infraclavicular incision (21) (Figure 1).

A 15-cm necklace incision (9, 28) situated 1 cm above and parallel to the clavicle was used in other patients to expose the supraclavicular plexus (Figure 2). Division of the platysma allows supraclavicular nerves identification and preservation (Figure 3). The infraclavicular part of the plexus was explored through the deltopectoral incision.

The phrenic nerve was identified over the surface of the anterior scalenus muscle, and the spinal accessory nerve was detected at the medial border of the trapezius muscle.

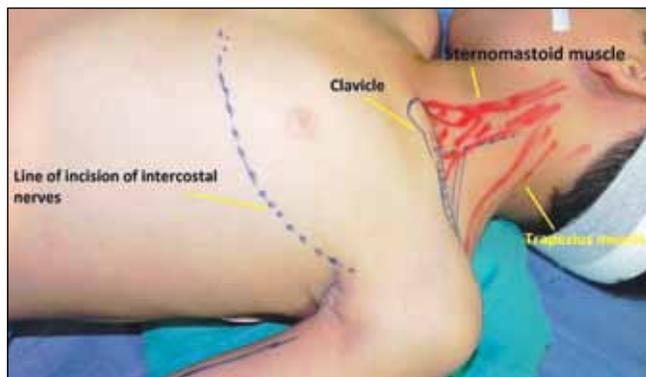


Figure 1: Drawing for classical incision of supraclavicular area and incision for intercostal nerves.

The C5, C6, C7 nerve roots were found at the lateral border of the anterior scalenus muscle (Figure 4). The same route was employed for identification of the anterior and posterior division of the upper trunk and the suprascapular nerve.



Figure 2: Supraclavicular transverse incision.



Figure 3: Supraclavicular nerves.

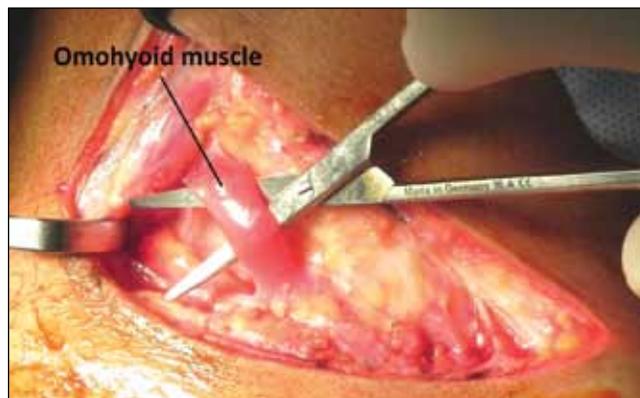


Figure 4: Omohyoid muscle dissection.

The infraclavicular brachial plexus was reached via a deltopectoral incision with a section of the pectoralis minor muscle. Following mobilization of the musculocutaneous nerve and retraction medially of the lateral cord and the axillary artery, the radial nerve was detected at the point where it passed superficial to the lower border of the subscapularis muscle.

According to Socolovsky et al. (35), plexoplexal repair with cable nerve grafts (Figure 5) was performed if there was root rupture and the treatment strategy included reanimation of the suprascapular and musculocutaneous nerve in most of the patients.

After confirmation of avulsion nature of the injury, neuritization by extraplexus source was the only solution.

In nineteen patients reinnervation of the suprascapular nerve was done by spinal accessory (Figure 6). After stimulation of the spinal accessory nerve by nerve stimulator, the nerve was transected distal to the last branch of the three supling trapezius. The proximal stump was then sutured to the distal stump of suprascapular nerve with 10/0 prolene or nylon sutures under surgical microscope magnification, or glued by fibrin glue. The reinnervation of musculocutaneous nerve was done through different methods. In this study if lower roots C8, T1 were intact, Oberlin procedure was the best choice (Figure 7): A longitudinal incision was made along

the upper medial surface of the arm and the ulnar nerve was explored and detected by the use of a nerve stimulator. The epineurium was opened and the fascicles were exposed. The posteromedial fascicle containing muscular fibers to flexor carpi ulnaris was carefully isolated and transected.

The musculocutaneous nerve was detected between the coracobrachialis and biceps brachii muscles (Figure 11), and followed by dissection to the point in which a muscular branch enters the biceps brachii. This fascicle was transected sharply and sutured to the ulnar nerve fascicle, again under microscope magnification and by prolene 10/0 sutures, or Nylon, or glued by fibrin glue.

In total traumatic patients, the Intercostal nerves were used to reinnervate musculocutaneous (Figure 8); they are harvested via a thoracic exposure and subperiosteal dissection along the inferior surface of the ribs. A long incision beginning high in the axilla and running inferiorly then curved beneath the ipsilateral nipple, corresponding to the inferior margin of the fifth rib.

The pectoralis major muscle is reflected medially and superiorly (Figure 9). Electrocautery is used to open the periosteal sleeve, and a periosteal elevator used to dissect the periosteum from the internal surface of the rib (Figure 10). Sharp

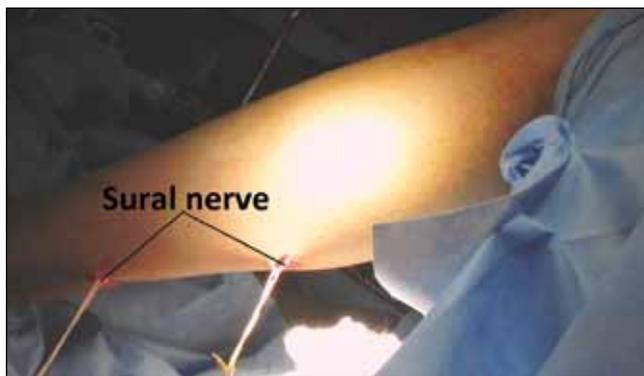


Figure 5: Multiple staples for sural nerve harvesting.

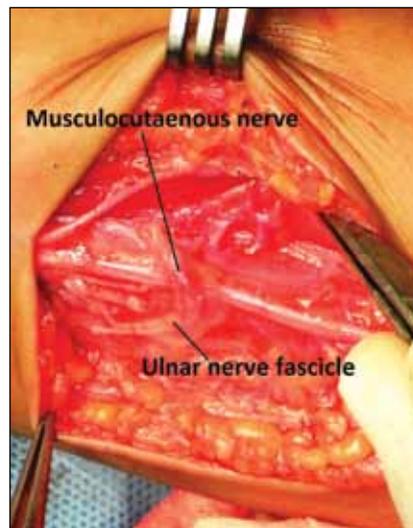


Figure 7: Oberlin procedure (motor fascicle of ulnar nerve to musculocutaneous nerve).

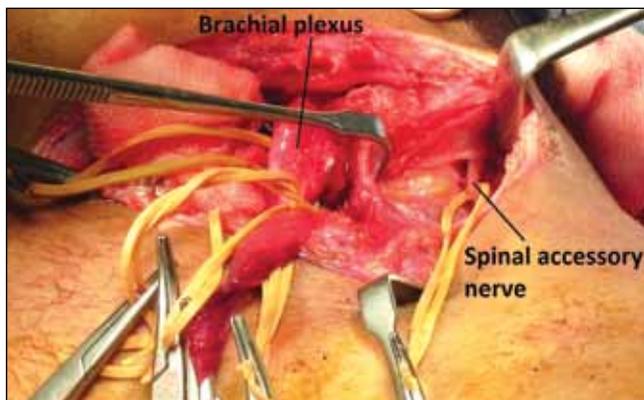


Figure 6: Exploration of the spinal accessory nerve.



Figure 8: Incision for intercostal nerves retrieval.



Figure 9: Elevating of pectoralis major muscle.

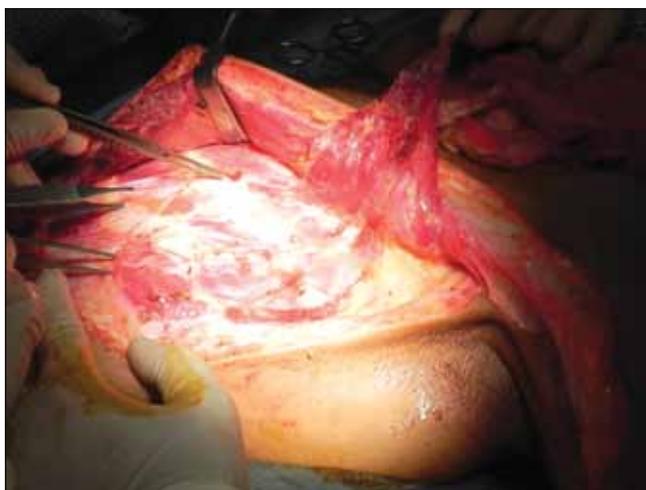


Figure 10: Elevation of pectoralis minor muscle.

dissection through the periosteum identified the intercostal nerve and intimately associated artery; great care should be used so as not to perforate the pleura, which lies immediately deep to the nerves (32) (Figure 12).

The affected upper extremity was immobilized in a sling for 3 weeks, with the elbow flexed at 90°. This process was followed by intense physiotherapy training; initially, passive elbow extension exercises were encouraged to prevent joint contractures.

Statistical analysis:

Statistical analysis was performed using the 18.0 version of SPSS statistical software for windows. The *unpaired Student t* test was used in the comparison between pre- and post-operative shoulder functions, elbow functions, wrist extension functions and pain. *Pearson correlation* was used between age, pre-operative period and follow up period with each of post-operative pain, shoulder functions, elbow functions and wrist extension functions. P values less than 0.05 were considered significant.

RESULTS

Various procedures were used in this study; one of the most common procedures was spinal accessory nerve transfer to the suprascapular nerve and muscle grading revealed 78.95% (15/19 patients) regaining functional muscle power (M5-M3), 10.50% (2/19 patients) regaining non functional muscle power (M1-M2) and only 10.5 % (2/19 patients) with non innervated muscle (M0).

For the Oberlin procedure, the other common procedure, the muscle grading showed 83.33% (5/6 patients) regaining functional muscle power (M5-M3), 16.67% (1/6 patients) regaining non functional muscle power (M1-M2) and no cases with non innervated muscle.

As regards intercostal nerve transfer to the musculocutaneous nerve, muscle grading revealed 62.5% (5/8 patients) regaining functional muscle power (M5-M3), 25.0% (2/8 patients)

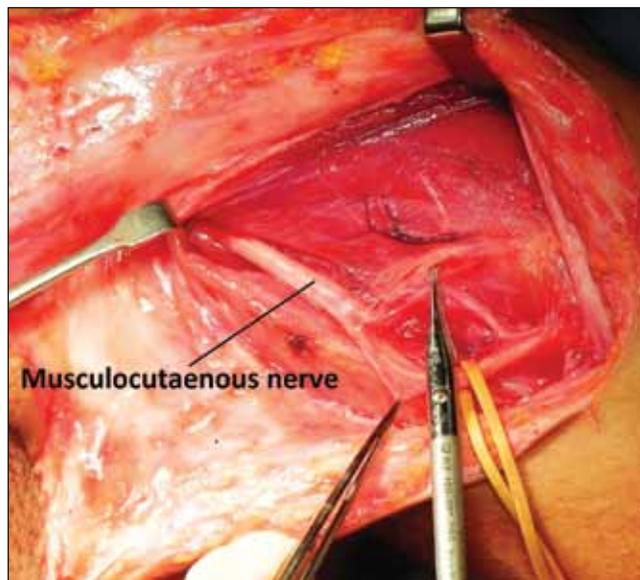


Figure 11: Musculocutaneous nerve exploration.

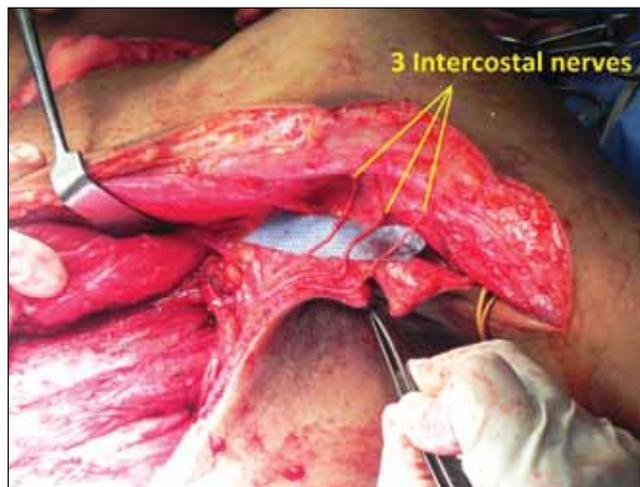


Figure 12: Three intercostal nerves ready for neuritization.

regaining non functional muscle power (M1-M2) and only 12.5 % (1/8 patients) with non innervated muscle (M0).

In general, the shoulder, elbow and wrist extension functions were significantly improved early post-operatively ($P < 0.001$). In addition, the post-operative improvement of shoulder, elbow and wrist extension functions had significant negative correlations with the pre-operative elapsed time ($P < 0.05$, $P < 0.01$ & $P < 0.05$ respectively), accompanied by a significant positive correlation with post-operative follow up period ($P < 0.05$) (Figure 14 A-C, Table III). However, no significant correlations were noticed between improvement and age of patients ($P > 0.05$). While, the post-operative pain severity

correlated negatively with the age of patients and follow up periods, it had no correlation with pre-operative periods.

DISCUSSION

Different methods of repair have been described in attempts to regain mobility and sensation, especially for the proximal parts of the affected limb (shoulder and elbow) (2).

In the present study, early results of spinal accessory nerve transfer to suprascapular nerve procedure regained 78.95% of functional shoulder muscle power (M5-M3), 10.50% of non functional muscle power (M2-M1) and only 10.5 % of non innervated muscle (M0).



Figure 13A-C: Preoperative.

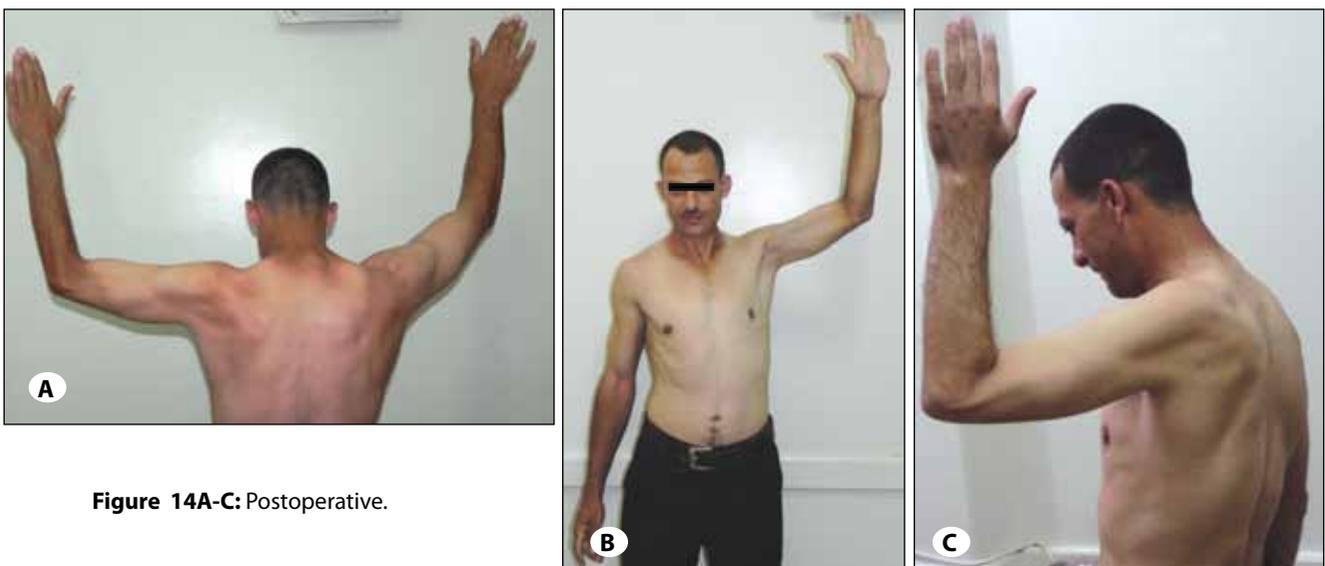


Figure 14A-C: Postoperative.

Table III: Shoulder, Elbow and Wrist Extension Functions Improvement and Its Correlations to Age, Pre-Operative Elapsed Time and Post-Operative Follow Up Periods of all Procedures

Item	Before surgery (Mean ± SD)	After surgery (Mean ± SD)	Pearson correlation (r) with		
			Age	pre-operative period	Follow up period
Shoulder	0.00 ± 0.00	3.00 ± 1.68***	-0.276 ^{NS}	-0.428*	+ 0.440*
Elbow	0.00 ± 0.00	3.20 ± 1.60***	- 0.331 ^{NS}	-0.538**	+ 0.412*
Wrist Ex	0.00 ± 0.00	1.44 ± 1.38***	- 0.229 ^{NS}	- 0.412*	+ 0.493*
Pain severity	2.56 ± 0.50	0.56 ± 0.55***	-0.499*	0.205 ^{NS}	- 0.403*

NS (non significant) = P > 0.05, * = P < 0.05, ** = P < 0.01, *** = P < 0.001.

The present results are in line with that of Terzis and Kostas (42) who reported that the spinal accessory to suprascapular nerve transfer was better than nerve transfer to the axillary nerve. In addition, Terzis and Papakonstantinou (40) reported excellent recovery of shoulder abduction (grade 3 or more) in 79% of the patients and in 55% of the patients for external rotation. Bertelli and Ghizoni (6) achieved an average range of arm abduction up to 122 degrees, and external rotation up to 118 degrees in patients with upper lesion of the roots. Venkatramani et al. (43) obtained somewhat lower ranges with 66 degrees for arm abduction and 44 degrees for external rotation. Suzuki et al. (39) obtained similar average shoulder abduction of 77.1 degrees, but shoulder external rotation was far lower with only 16.7 degrees.

Malesy et al. (26) however reported that the reinnervation of the shoulder in patients with upper brachial plexus palsy following the suprascapular nerve neurotization is disappointingly low.

Probably the best solution is dual-nerve transfer to both the suprascapular and axillary nerves (1). Two of the nineteen patients in this study had this policy with satisfactory results.

It is fact that the first priorities in brachial plexus repair are restoration of full range and strong elbow flexion, shoulder stability, active arm abduction, and some external rotation (37). The improvement of all functions is equally important since these enable elbow movements through a more functional range (29).

In the present study, early results of Oberlin procedure (neurotization of the musculocutaneous nerve) revealed 83.33% of elbow functional muscle power (M5-M3), 16.67% of non functional muscle power (M2-M1). In addition, the intercostal nerves transfer to musculocutaneous nerve, revealed 62.5% elbow functional muscle power (M5-M3), 25.0% of non functional muscle power (M2-M1) and only 12.5 % of non innervated muscle (M0).

The restoration of elbow flexion may be achieved through reinnervation of the musculocutaneous nerve (27). excellent results achieved when accompanied by reinnervation of the suprascapular nerve since the supra- and infrascapular muscles are important for initiation of the active arm abduction and some external rotation.

In 2005, Mackinnon et al. (25) reported M4 or better strength of elbow flexion in six patients in the series with dual transfers for elbow flexion.

Early results of elbow flexion restoration by Chuang et al. (15) using intercostal transfer to the musculocutaneous nerve demonstrated 66% success. Chuang (13) reported an average of 80% success (M 3).

Nerve transfers using collateral branches of the brachial plexus constitute a distal form of the intraplexal nerve transfer that generally yields better results because of the higher number of motor fibers and more physiologic reconstruction. Furthermore, they offer some advantages to the classic intraplexal transfer, such as insignificant axonal mixing, absence of mass or cross innervation, anastomosis close to the target muscle, and more precise evaluation of donor nerve functional validity compared to that of the proximal nerve stumps (33).

Early results for elbow flexion, published by Oberlin in the mid 1990s, have convinced a significant number of surgeons to adopt distal transfers as a very successful technique (30).

One of the main advantages of distal procedures, besides the short distance to the target muscle, is the selective orientation of the growing axons toward the desired target nerve. This advantage is not present when the graft is short and directed towards a more proximal target like the anterior division of the upper trunk, which could cause some of the growing axons intended to follow elbow flexors to 'get lost' and be directed towards other motor or sensory targets (35).

In the present study, the post-operative improvement of shoulder, elbow and wrist extension functions had significant negative correlations with the pre-operative elapsed time (P < 0.05, P < 0.01 & P < 0.05 respectively). So the shorter the preoperative time delay the better the results.

The negative effect of time delay from trauma to surgery in brachial plexus reconstruction is reflected unanimously in the literature. The mean time from trauma to surgery in the group of responders was almost half that of non-responders, a difference that was highly statistically significant (18,23). Jivan et al. (23) suspected that time to surgery may be an even stronger predictor of outcomes with long grafts, possibly because of particular features of this technique, including

distal neurotomy site fibrosis that could impede the growing axon as it strives to pass through on its way to the target end organ.

In this study, the close follow up and intense regimen of rehabilitation physiotherapy revealed a significant positive correlation between the follow up period and muscle functions improvement ($P < 0.05$).

The importance of an intense and prolonged rehabilitation program on the final result of a brachial plexus injury is well known at many centers (8,12,20,21).

Despite the encouraging results with intercostal nerve transfer, greater functional success has been achieved by transferring intact branches of the ulnar or median nerves directly to the motor branches of the biceps and/or brachialis. Early results demonstrated 75 to 100% of patients achieved antigravity (M3) biceps strength or better, and recent results show between 75 and 94% M4 strength (31,38). So I stucked in dealing with the patients to use intercostal nerve transfer only when there were no possibility for oberlin procedure.

In conclusion, early intervention for traumatic brachial plexus palsy is highly recommended to get better results of motor function and pain relieve. The Oberlin procedure for elbow flexion restoration is preferable. Spinal accessory nerve transfer to suprascapular nerve is a good routine technique for shoulder function restoration.

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