# New proposed prevertebral approach for turned on normal contralateral C7 as a donor for avulsed brachial plexus

Ahmed Yehia El-Hoseny [$ ϴ]. Mohammed Reda Ahmed [* ϴ], Youssef Hussein [# ϴ]

[ϴ] Faculty of Medicine, Zagazig University, * Department of General Surgery, Plastic & Reconstructive unite, $ Department of Neurosurgery and # Department of Anatomy

**Abstract: Background:** Great progress of surgical treatment had been made in brachial plexus injuries during recent two decades, however, there are still more challenges. It needs more advancing and a lot of work from surgeons and neurosurgeons. **Aim:** To propose a new surgical approach for neuritization of avulsed brachial plexus (BP). **Methods:** Anatomical study by dissection of the brachial plexuses on both sides in 6 male cadavers in five steps. **Results:** The mean value of the length of C7 (5.73Cm ± 0.12) was significantly longer than that of C5, C6, C8 and T1 on both sides. Complete C7 length in step 4 with prevertebral approach (8.95 Cm ± 0.04) was significantly longer than that of C7 in step 3 with subcutaneous tunnel (7.00 Cm ± 0.11, P < 0.001). Moreover**,** in proposed procedure 5 (with turning of the complete C7 root from behind the vertebral artery to the medial side of the artery) was significant excesses of the length of complete C7 (0.68 Cm ± 0.07) when compared with that of proposed procedure 4 and procedure 3 (-0.25 Cm ± 0.02, -8.95 Cm ±0.04, P < 0.001). **Conclusion:** We proposed by cadaveric dissection a new passageway for turned on complete C7 to neuritize affected Bp just infront of the vertebral column, and we proved the statistical significance of this approach. Moreover, after complete release of C7 from turning around vertebral artery the neuritization will be very lax with extra length.

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## 1. Introduction

The brachial plexus is composed of a complex network of nerves, passing from the neck to the axilla, which supplies motor, sensory and sympathetic fibers to the upper limb. It is formed by the union of the ventral rami of the lower four cervical nerves and the greater part of the ventral ramus of the first thoracic nerve [1-3].

The number of severe brachial plexus injuries requiring proper management has increased over the past several years, largely in part to improved prehospital emergency, and advanced life support techniques [4]. In spite of increased experience in the management of these severe brachial plexus injuries (BPI), there remains considerable challenge in dealing with these devastating injuries [1, 5, 6].

The overall target of reconstruction should be directed toward regaining of many important functions of the upper extremity (i.e., shoulder stability, elbow flexion, elbow extension, protective sensation in the hand and if feasible, hand reanimation [1].

It is well known that, the best results in brachial plexus surgeries are achieved when directly suturing proximal stump of ruptured rootlet with its distal stump or using shorter bridge graft between them [7].

Total root avulsion injuries of the brachial plexus considered irreparable. For these cases and in a period of denervation less than 1 year, nerve transfer is used to innervate the affected arm [8,9].

Donner nerves for reinnervation of total root avulsion injuries are always insufficient [10]. Many donor nerves had been used for brachial plexus innervations, like phrenic[11, 12], spinal part of accessory[13], intercostal[14] nerves, and motor branches of the cervical plexus[15].

Gu et al.[16] used the contralateral C7 nerve root as a donor. He divided his work in 2 stages; firstly, he elongated the root by sural nerve graft. After that, he resected the neuroma and transferred the sural graft to selected recipient nerves.

The gross anatomy of the brachial plexus is well known, but the internal anatomy especially that of C7 is seldom mentioned. Narakas [17] published a scheme for cross sectional localization of C7 and its distribution to the posterior cord of the brachial plexus, median, pectoral, musculocutaneous and ulnar nerves.

Slingluff et al. [18] presented a detailed and advanced quantitative microanatomy of the brachial plexus in human. According to his work, main contributions from C7 to lateral cord (44%) and to posterior cord (44%). C7 fibers to lateral cord were mainly sensory to median nerve. C7 fibers to posterior cord were mostly motor to the radial nerve.

The most important muscles with a C7 contribution do not have C7 as their single or dominant innervation. On this base, the usage of normal contralateral C7 is safe as a donor for reinnervation[18].

As stated before that, the major challenge with avulsions is the lack of adequate proximal intraplexus donors (roots) in continuity with the spinal cord [1]. Therefore, the aim of our study is to propose a shorter approach to neuritize avulsion injuries of the brachial plexus from contralateral C7 root.

## 2. Material and Methods:

Six male formalin-fixed adult Egyptian cadavers used in this work. All measurements made using 1) a protractor to define the distance between points, 2) a Diamond Master Vernier Calipers to measure the distances and 3) an orthopedic goniometer. We dissected on the brachial plexuses of both sides in them in five steps.

- First step: Deep dissection of posterior triangle and cutting of the omohyoid muscle and scalenous anterior were done. Then, we measured the length of each root from side of vertebral column to the level of formation of the trunks in right and left sides.
- Second step: Dissection of the whole C7 root as we call it, (it is composed of C7 root, middle trunk, and the divisions of middle trunk until their junction with lateral and posterior cords) done and measured.
- Third step: Turning of the complete contralateral C7 root in front of pretracheal strap muscles as a model for subcutaneous tunnel done, and the distance from the end of the turned complete c7 and contralateral plexus measured denoting graft length required.
- Forth step: In present study we proposed prevertebral retroesophageal tunnel for cross innervation from C7 to contralateral brachial plexus. Therefore, we had turned on the complete C7 root on itself to lie just in front of the vertebral column.
- Fifth step: After removal of the transverse process of C6, and turning of the complete C7 root from behind the vertebral artery in the same tunnel (prevertebral retroesophageal).

* In step 2, we compared the length of C7 roots in step 1 and the complete C7 (c7 root + middle trunk + divisions of the middle trunk).

* In step 3, we estimate the desirable cable graft length that needed to connect the complete C7 to contra lateral BP.

* In step 4, we measured the length needed for these roots to reach contralateral plexuses in minus numbers.

* In step 5, we measured the overriding length of these roots on contralateral plexuses in plus numbers.

**Statistical analysis**:

Statistical analysis performed using the 18.0 version of SPSS statistical software for windows (SPSS Inc. Chicago, IL, USA). All data expressed as mean ± SE (Standard error). Student's t. test: Unpaired *t.* test used to compare means of different groups, and paired t. test to compare means of same groups. Analysis of variance (ANOVA of F test): For comparison of means of more than two groups used also.

For all above statistical tests, P value of >0.05 indicates non-significant results, and P value of <0.05 indicates a significant results.

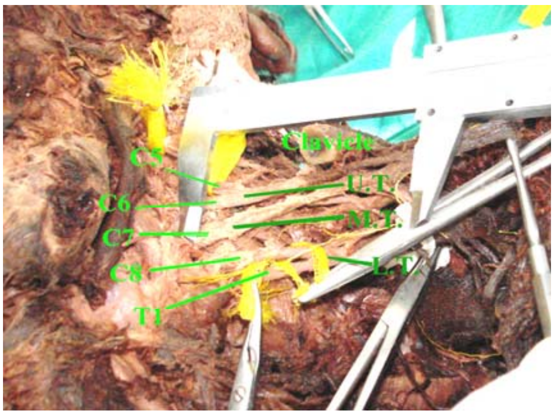


**Fig.1: Photograph showing roots measurement.**

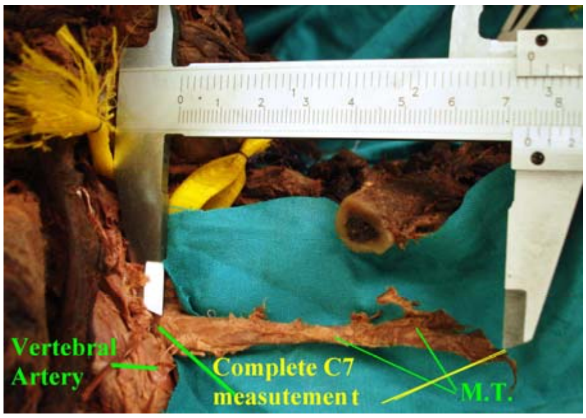


**Fig.2: Photograph showing complete C7 measurement.**

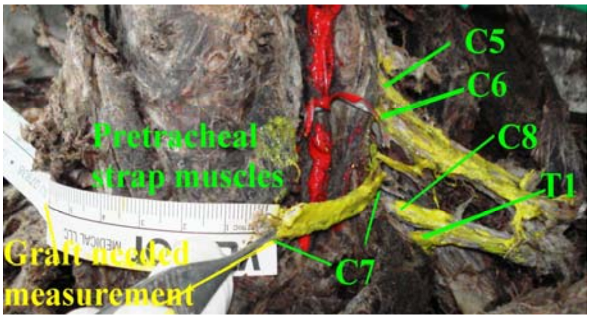


**Fig.3: Photograph showing proposed subcutaneous tunnel.**

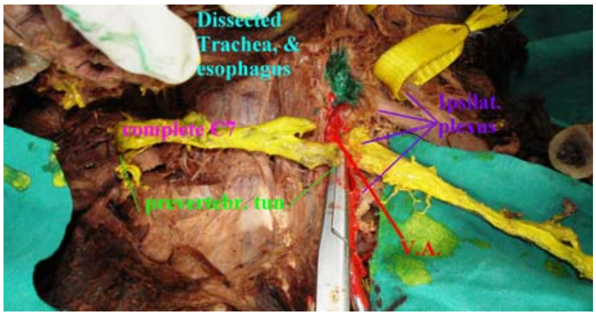


**Fig.4: Photograph showing proposed prevertebral approach.**

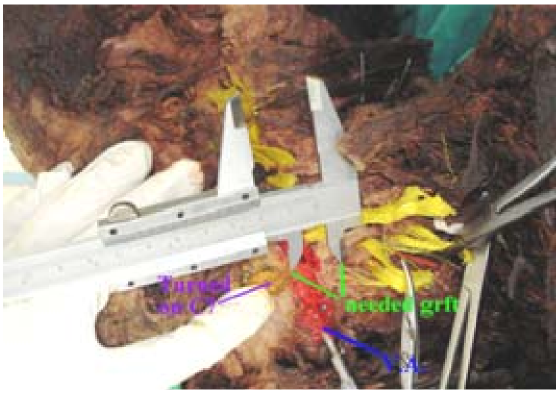


**Fig.5: Photograph showing estimated length of graft in step 4**

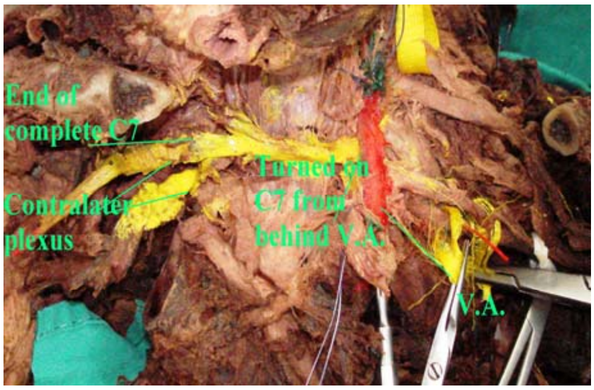


**Fig.6: Photograph showing bypassing the turning around vertebral artery.**


**Fig.7: Photograph showing step 5 with extra length.**

**3. Results**

Table (1) shows the length of the dissected roots (C5, C6. C7, C8, and T1), from side of the vertebral column level to the level of formation of the trunks. It was found that, there were no significant differences between the right and left sides in the length of any dissected roots (P > 0.05).

Table (2) and figure (8) show comparison between the mean values of the length of C7 (mean± SE) and that of other roots in both right and left sides. It was found that the mean values of the length of the right C7 (5.73 ± 0.12) was significantly longer than that of C5, C6, C8 and T1 (4.4 ± 0.25, 4.12 ± 0.07, 3.7 ± 0.19 and 4.05 ± 0.19 respectively) (P < 0.01, P < 0.001, P < 0.001 and P < 0.001 respectively). The same significance was found also in the left side. The length of the left C7 root (5.70 ± 0.13) was significantly longer than that of C5, C6, C8 and T1 (4.35 ± 0.21, 4.15 ± 0.110, 3.67 ± 0.18 and 4.02 ± 0.20 respectively, (P < 0.001).

Table (3) and figure (9) identify the comparison between the mean values of the complete

C7 length (mean ± SE) and that of C7. It was clear that complete C7 length (8.95 ± 0.04) was significantly longer than that of C7 (7.00±0.11, P < 0.001).

Table (4) and figure (10) represent the comparison between the length needed in step 3, 4 & 5 to reach contralateral BP. It was found that, in proposed procedure 5 we had significant excess of the length (0.68 ± 0.07) when compared with that of proposed procedure 4 and procedure 3 (-0.25 ± 0.02, -8.95±0.04, P < 0.001).

**Table 1: The length of each dissected root from intervertebral level to the level of formation of the trunks.**

| N= 6 | Mean ± SE | | P value |
|---|---|---|---|
| | Right | Left | |
| C5 | 4.4 ± 0.25 | 4.35 ± 0.21 | 0.363 (NS) |
| C6 | 4.12 ± 0.07 | 4.15 ± 0.11 | 0.679 (NS) |
| C7 | 5.73 ± 0.12 | 5.70 ± 0.13 | 0.363 (NS) |
| C8 | 3.7 ± 0.19 | 3.67 ± 0.18 | 0.363 (NS) |
| T1 | 4.05 ± 0.19 | 4.02 ± 0.20 | 0.175 (NS) |

**Table 2: Comparison between the mean values of the length of C7 (± SE) and the length of other roots in both right and left sides.**

| N= 6 | Right (Cm) | t test VS C7 | Left (Cm) | t test VS C7 |
|---|---|---|---|---|
| **C7** | 5.73 ± 0.12 | | 5.70 ± 0.13 | |
| **C5** | 4.4 ± 0.25 | 4.822** (P < 0.01) | 4.35 ± 0.21 | 5.343*** (P<0.001) |
| **C6** | 4.12 ± 0.07 | 11.610*** (P < 0.001) | 4.15 ± 0.11 | 9.076*** (P< 0.001) |
| **C8** | 3.7 ± 0.19 | 9.175*** (P <0.001) | 3.67 ± 0.18 | 8.994*** (P< 0.001) |
| **T1** | 4.05 ± 0.19 | 7.507*** (P< 0.001) | 4.02 ± 0.20 | 7.054*** (P< 0.001) |

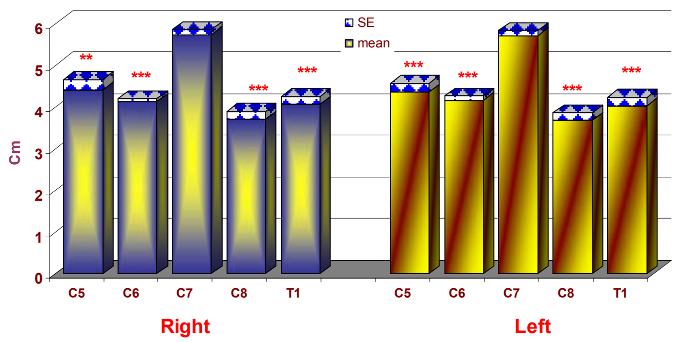


**Figure 8: A histogram illustrates the comparison between the mean values of the length of C7 (± SE) and the length of other roots in both right and left sides.**

**Table 3: Identifies the comparison between length of C7 and complete C7.**

| N=6 | Step 1 | Step 2 |
|---|---|---|
| $\overline{X}$ | 7.00 | 8.95 |
| SE ± | 0.11 | 0.04 |
| t test | 22.709*** | |
| P value | <0.001 | |

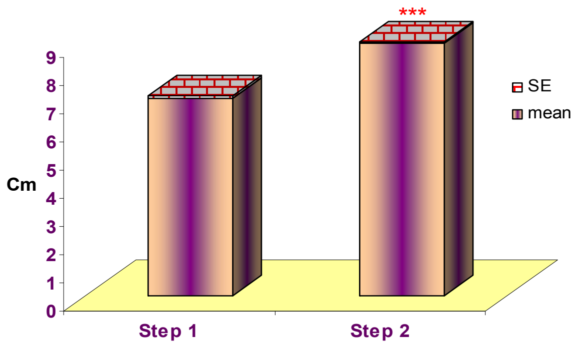


**Figure 9: A histogram illustrates the comparison between length of C7 and complete C7.**

**Table 4: Demonstrates the length needed in step 3, 4 & 5 to reach contralateral sides.**

| **N=6** | **Step 3** | **Step 4** | **Step 5** |
|---|---|---|---|
| $\overline{X}$ | -8.95 | -0.25 | 0.68 |
| **SE ±** | 0.04 | 0.02 | 0.07 |
| **F** | | P < 0.001 | |
| **P of LSD VS step 3** | | P < 0.001 | P < 0.001 |
| **P of LSD VS step 4** | | | P < 0.001 |

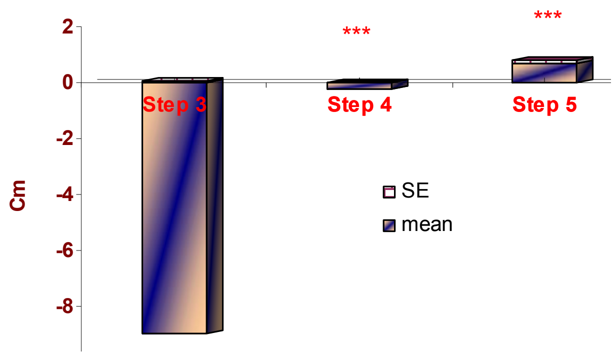


**Figure 10: Illustrates the length needed in step 3, 4 & 5 to reach contralateral sides.**

## 4. Discussions

Neurotization techniques were introduced at earlier times in the twentieth century, giving hope for the restoration of severe brachial plexus injuries [19]. This initial surgical enthusiasm, unfortunately, gave way to a more pessimistic attitude of "wait and see," as almost all of these earlier surgical techniques were unsuccessful in restoring limb function. A nonoperative approach was eventually advocated for all brachial plexus injuries at that time [20].

Introduction of the art of microsurgery in peripheral nerve problem and the establishment of the principle of tension free repair brought several new approaches to brachial plexus reconstruction, especially when dealing with supraclavicular lesions with multiple avulsions [21,22]. A variety of extraplexus motor and sensory donors has been advocated to neurotize selected functions in order to achieve restoration of the performance of the shoulder, elbow, and hand. Yeoman and Seddon[23] introduced later neurotization of the musculocutaneous nerve with intercostal nerve transfer. In addition, use of branches of the ipsilateral cervical plexus[24], contralateral lateral pectoral nerve[25], accessory nerve[26], hypoglossal nerve, phrenic nerve and contralateral C7[26,27] selective contralateral C7[28,29], and selective ulnar nerve to musculocutaneous has been championed by different researchers[30].

Restoration of functional finger flexion and extension has remained largely unobtainable dream following avulsion injuries. The prolonged time required for nerve regeneration results in prolonged muscle denervation that lead to muscle atrophy and subsequent fibrosis, leaving the muscles inadequate to generate the force required to move the fingers [1].

The experimental work of Carlstedt [31] demonstrated that reimplantation of avulsed roots in spinal cord leaded to some improvement of muscle functions. Inspite of that, functional outcome compromised due to severe cocontraction. Further experimental work needed before this approach can have any meaningful clinical application.

Whenever possible, the use of intraplexus motor donors for neurotizations is preferable. Intraplexus donors have a larger number of axons than gained from extraplexus sites, and thereby increase the chances for successful neurotization. The overall results from the study done by Terzis et al.[32] and analysis of clinical series of 204 operated cases, including 112 cases with multiple avulsions, demonstrated that intraplexus donors consistently yielded the strongest contractile force, regardless of the muscle target. So Extraplexus nerve transfers should be considered second choice alternatives. Allieu et al.[33] reported a 66% success rate for restoring elbow flexion following neurotization by intraplexus donors (C5 or C6). This was superior to neurotization with intercostals or the accessory using an interposition nerve graft. Other authers like Narakas and Hentz[34] considered plexoplexal transfers as far more reliable than extraplexal, and even superior to muscle transfers in the reconstruction of shoulder abduction, elbow flexion, or wrist extension. Kawai et al.[12] reported that the outcome was better in 80% of avulsion injuries treated with the combined use of intraplexus and extraplexus donors. We planned our proposal for the treatment of multiple avulsion cases of traumatic brachial plexus injury, not far from these whole ideas. We did plexoplexal neuritization from contralateral C7 by a new short tunnel, to gain the maximal plexal donors without deficits.

Long graft failures are a big problem in BP primary surgery. Hattori et al.[35] tried to solve this problem by the use of vascularized nerve grafts, i.e., vascularized ulnar based on the superior ulnar collateral vessels. Such vascularized grafts are able to maintain their blood supply and have survived transfer even after being placed in a scarred bed. Moreover, the intraneural environment is optimally preserved and axonal carry-through would not compromise. Birch et al. [36] and Addas et al[37] used the ulnar nerve as a vascular graft based on the whole ulnar artery, thereby sacrificing one of the main arteries to the hand. All of the results were more favorable as compared to conventional nonvascularized nerve grafting [1]. In other way and in our work we can preserve some function of ulnar and median nerves by doing plexoplexal neuritization in a short circuit. The rational for our proposal depends on the following:

1- C7 root neither innervate any muscle as single nor as a dominant innervator, and so no deficit usually occurred after its' taking as donor.
2- The length and direction of C7 root is unique for cross innervation.
3- Prevertebral tunnel is short enabling us to do neuritization with minimal graft length.
4- If we add release of C7 from medial side of the vertebral artery, and avoiding the whole turn of C7 around the (V.A.), we will gain extra length making the neuritization more and more lax without any need for grafts.

It is clear that, anatomical studies performed on cadavers or in life surgery work. When carrying studies on cadavers, the surgeon has more time and range of actions while bleeding is quite minimal or even no. However, rigor, tissue decay, identification of small blood and lymph vessels and nerves, creates some discomfort [38]. On the other hand, surgeon does not feel this discomfort in operating room and he can use electrostimulation for identification of motor nerves under light relaxation of the patient. Therefore, we recommend following our work by many anatomical studies during life surgeries to gain previously mentioned merits. Moreover, to know more about avulsed roots, their positions, mobility, and pliability. Also after taking into the consideration that, the normal roots pass from behind in the anterolateral direction, which is different from avulsed roots, which may become more volar and medial.

**5. Conclusion:**

The use of intraplexus motor donors for neurotizations of traumatized BP is preferable. In cases of multiple avulsions of the roots, ipsilateral intraplexus donors are not available. Taking of contralateral complete C7 does not affect the normal upper limb. We proposed a new passageway for turned on complete C7 to neuritize affected Bp just infront of the vertebral column, and we proved after cadaveric dissection statistically the significance of this approach. In addition, we added that, after complete release of C7 from turning around vertebral artery the neuritization will be very lax with extra length.

**References**


1- Terzis J. K., Vekris M.D., Soucacos P. N. (2001): Brachial Plexus Root Avulsions. *World J. Surg*., 25:1049–1061.
2- Williams P.L., Warwick R., Dyson M., Bannister L.H. (2005): Gray's anatomy. Churchill Livingstone, Edinburgh, pp 1130–1137.
3- Cornish P.G. and Leaper C. (2006): The sheath of the brachial plexus. *Anesthesiology* 105:563–565.
4- Neal J.M., Hebl J.R., Gerancher J.C., Hogan Q. (2002): Brachial plexus anesthesia: essentials of our current understanding. *Reg. Anesth. Pain Med*., 27:402–428.
5- Aszmann O.C., Rab M., Kamolz L., Frey M. (2000): The anatomy of the pectoral nerves and their significance in brachial plexus reconstruction. *J. Hand Surg*., 25A:942–947.
6- Merrell G.A., Kimberly A.B., Katz D.L., Wolfe S.W. (2001): Results of nerve transfer techniques for restoration of shoulder and elbow function in the context of a meta-analysis of the English literature. *J. Hand Surg.* 26A:303–314
7- Narakas A. (1982): Les neurotisations on transferts dans les lesions du plexus brachial. Neurotization or nerve transfer for brachial plexus lesions. Ann. Chir. Main, 1(2):101–118 (translated abstract).
8- Narakas, A. O. (1987): Thoughts on neuritization or nerve transfers in irreparable nerve lesions. In Terzis J. K. (Ed.), Microreconstruction of the nerve injuries. Philadelphia: Saunders, P. 447.
9- Narakas A.O. (1990): Brachial plexus injury. In Mc-Carthy J. G. (Ed.), Plastic surgery. Philadelphia: Saunders, P. 477.
10- Doi K, Muramatsu k, Hattori Y, Otsuka K, Tan S, Nanda V, Watanabe M: Restoration of prehension with the double free muscle technique following complete avulsion of the brachial plexus. J. Of Bone and Joint Surgery, 82: 652-66.
11- Gu Y. D., Wu M. M., Zhen, Y. L., (1989): Phrenic nerve transfer for brachial plexus motor neuritization. *Microsurgery*, 10: 287–289.
12- Kawai H., Kawabata H., Masada K., Ono K., Yamamoto K., Tsuyuguchi Y., and Tada, K. (1988): Nerve repairs for traumatic brachial plexus palsy with root avulsion. Clin. Orthop., 237:75.
13- Allieu Y., Privat J. M., Ad-Bonnel F., (1988): Neuritization by means of spinal nerve (accessories) in root avulsion of the brachial plexus. In *Brunelli G*. (Ed.) Text book of microsurgery, Milan: Masson, P: 798.
14- Nagano A., Tsuyama N., Ochiai N., (1989): Direct nerve crossing with the intercostal nerve to treat avulsed brachial plexus. *J. Hand Surg*., 14 A : 980-984.
15- Pei L, Liang B, Yin Y. (1997): Treatment of nerve root avulsion of brachial plexus by nerve transfer. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi.*, 11:30-31
16- Gu Y. D., Zhang G. M. and Chen, D. S., Chen D.S., Cheng X.M., Zhang L.Y., Yan J.G., Cai P.Q., Shen L.Y., (1991): Cervical nerve root transfer from contralateral normal side for treatment of brachial plexus root avulsions. *Chin. Med. J. (Engl.*) 104: 208-211.
17- Narakas, A., (1978): Surgical treatment of traction injuries of the brachial plexus. *Clin. Orthop*., 133: 71-75.
18- Slingluff CL., Terzis JK. Edgerton MT. (1987): The quantitative microanatomy of brachial plexus in man: reconstructive relevance. In Terzis J. K. (Ed.), microreconstruction of nerve injuries. Philadelphia: Saunders, Pp. 285-324.
19- Tuttle H., (1913): exposure of the brachial plexus with nerve transplantation. *J.A.M.A*., 61:15.
20- Nelson K.G., Jolly P.C., Thomas P.A. (1968): Brachial plexus injuries associated with missile wounds of the chest. A report of 9 cases from Vietnam. *J. Trauma*, 8:268.
21- Narakas A. (1977): The surgical management of brachial plexus injuries. In Reconstructive Microsurgery, vol. 1, Daniel R.K., Terzis J.K. (ed), Boston, Little Brown.
22- Millesi H., (1988): Brachial plexus injuries: nerve grafting. Clin. Orthop., 237:36.
23- Yeoman, P.M., Seddon, H.J., (1961): Brachial plexus injuries. Treatment of the flail arm. J. Bone Joint Surg., 43B:493.
24- Brunelli, G., (1980): Neurotization of avulsed roots of the brachial plexus by means of anterior nerves of the brachial plexus. *Int. J. Microsurg. 2*:55.
25- Vekrisa MD, Soucacosbf1 PN( 2001): Post-traumatic brachial plexus paralysis: current management of reconstruction. *J orthop. And Trauma*, 15: 67-83.
26- Allieu Y., Privat J.M., Bonnel F. (1984): Paralysis in root avulsion of the brachial plexus:

neurotization by the spinal accessory nerve. *Clin.Plast. Surg.*, 11:133.
27- Gu Y, Xu J, Chen L, Wang H, Hu S (2002): Long term outcome of contralateral C7 transfer: a report of 32 cases. *Chin Med J (Engl)* 115:866–868.
28- Waikakul S, Orapin S, Vanadurongwan V (1999): Clinical results of contralateral C7 root neurotization to the median nerve in brachial plexus injuries with total root avulsions. *J Hand Surg [Br]* 24:556–560.
29- Chen L, Gu YD, Hu SN, Xu JG, Xu L, Fu Y (2007): contralateral C7 transfer for the treatment of brachial plexus root avulsions in children- a report of 12 cases. *J Hand Surg*., 32:96-103.
30- Loy S., Bhatia A., Asfazadourian H., Oberlin, C. (1997): Ulnar nerve fascicle transfer onto the biceps muscle nerve in C5-C6 or C5-C6-C7 avulsions of the brachial plexus. Eighteen cases. *Ann. Chir. Main Memb. Super., 16*:275.
31- Carlstedt T.P. (1995) Spinal nerve root injuries in brachial plexus lesions: basic science and clinical application of new surgical strategies. *Microsurgery* 16:13-16.
32- Terzis J.K., Vekris M.D., Soucacos P.N., (1999): Outcomes of brachial plexus reconstruction in 204 patients with devastating paralysis. Plast. Reconstr. Surg., 104:1221.
33- Allieu Y., Chammas M., Picot, M.C. (1997): Paralysis of the brachial plexus caused by supraclavicular injuries in the adult. Long-term comparative results of nerve grafts and transfers. Rev. Chir. Orthop. Reparatrice Appar. Mot, 83:51.
34- Narakas A. and Hentz V., (1988): Neurotization in brachial plexus injuries: indications and results. Clin. Orthop. 237:43.
35- Hattori Y, Doi K, Ikeda K (2005): Vascularized ulnar nerve graft for reconstruction of a large defect of the median or radial nerves after severe trauma of the upper extremity. *J Hand Surg* [Am]; 30: 986–989.
36- Birch R., Dunkerton M., Bonney G., and Jamieson, A.M., (1978): Experience with the free vascularized ulnar nerve graft in repair of supraclavicular lesions of the brachial plexus. Clin. Orthop. 237:96.
37- Addas BM.J and Midha R (2009): Nerve Transfers for Severe Nerve Injury *Neurosurgery Clinics of North America* 20: 27-38.
38- Krauze H.R., Bremerich A., and Herrmann M., (1991) The innervation of the trapezius muscle in connection with radial neck dissection. J. Cran-Max-Surg., 19:87–89.

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