Brachial plexus trauma: contralateral C7 transfer evaluation

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Received 13 January 2020
Revised 02 February 2020
Accepted 16 February 2020
Published 23 February 2021

Journal of Current Medical Research and Practice
2021, 6:31–35

Background and aim

Root avulsion injury of brachial plexus is a serious injury. Many attempts have been made regarding contralateral transfer of C7 to restore hand function. We designed this work to evaluate efficacy of contralateral C7 (CC7) transfer in the management of avulsion root injury.

Patients and methods

Between 2015 and 2018, 11 patients with avulsion root injury were enrolled in the study. All of them were males. After the procedure, those patients were followed for at least 2 years to assess the effect of transfer on healthy limb function, sensory and motor recovery of the recipient nerves in the affected limb, and coordination between the healthy and affected limbs.

Results

It was noticed that three patients had finger and wrist flexion grade 3, whereas seven patients had flexion grade 2 and only one patient demonstrated grade 0. According to hand sensation recovery, nine patients of the group showed S2 recovery and two patients showed S1. All 11 patients included in this study have achieved good results by Elbow Mayo score system, in spite of only three patients achieving satisfactory result by Gilbert shoulder system score and eight patients had fair results.

Conclusion

Transfer of CC7 (total CC7 transfer) with direct repair for reconstructing limb function was significantly better than CC7 transfer with graft.

Keywords:
avulsion root, brachial plexus injury, contralateral C7 transfer

J Curr Med Res Pract 6:31–35

2357-0121

Introduction

Flail upper limb may be caused by severe traumatic brachial plexus injury (BPI) with involvement of all five roots. BPI is one the serious injuries especially in case of avulsion with nothing remained over the affected limb. It mainly results from motorcycle accidents [1].

Secondary to root avulsion in such cases, the mainstay of reconstruction is nerve transfer. Although there is reconstruction in stability of shoulder with elbow flexion, the function of hand is still a matter of a challenge to be reconstructed [2].

To restore hand function, there were many attempts regarding transfer of the contralateral C7 (CC7), but the results are unreliable and inconsistent. Management is mainly focused on type of intervention and morbidity [2].

Many studies reported that conservative therapy with pain relief had unsatisfactory results, especially in case of complete injury of root of brachial plexus. Management of avulsion lesions involves usage of procedures of neurotization because of interpositional grafting of nerve, and direct repair could not be done for these irreparable preganglionic injuries [3].

Recently, management is done with a combination of many procedures such as CC7 root donation, free muscle transfer, and neurotization with ipsilateral intraplexus and extraplexus nerve donors [4]. This work was deigned to evaluate efficacy of CC7 transfer in management of BPI.

Patients and methods

Patients

After obtaining approval from Local Ethical Committee of Faculty of Medicine at Assiut University, Egypt, a retrospective study was conducted in Hand and Microsurgery Unit at Orthopaedic and Trauma Surgery Department of Assiut University Hospital. Eleven patients with complete traumatic BPI avulsion type were enrolled in the period between 2015 and 2018.

Patients with neurological injuries other than brachial injuries, severe injuries of limbs with deformity, lung trauma, contractures affecting range of motion in affected limb, vascular affection of the extremity, and follow-up less than 2 years were excluded.

In our practice, a high-velocity accident resulting in a complete deficit with positive Horner's sign and no indication of recovery in any muscle groups at more than 1 month from the accident is sufficient to warrant exploration and reconstruction based on the operative findings.

In four patients, a direct repair was performed, whereas the other patients had nerve grafting. Whenever possible, MRI of the spine was done mainly on cervical part to help determine levels of injury. Usually, all patients were not subjected to electrodiagnostic studies.

Operative techniques

All the operations were done by the same group of surgeons. Root avulsion was confirmed by exploration. Studies of the other limb without any traumatic affection would have normal findings.

In seven cases, subcutaneous route to repair CC7 with nerve graft to division of lower trunk anteriorly was performed and others patients were subjected to retropharyngeal route to repair CC7 directly to anterior division of lower trunk, except in one case, which was done to posterior cord.

Postoperative

Physical therapy and electrostimulation therapy were started 4 weeks postoperatively. Patients were instructed to adduct their contralateral shoulder against resistance, while doing the action of the affected limb according to the recipient nerve.

Follow-up at the outpatient clinic was done at 2nd, 6th, and 10th week and then 3 months thereafter. Evaluation was performed for at least 2 years with the following: motor recovery based on British Medical Research Council scale, range of shoulder motion, recovery of sensation, and any complications at site of donation. Donor site affection was considered if any motor or sensory deficit remained for more than 6 months with no improvement [5].

Range of follow-up was between 25 and 39 months, with a mean of 35 months. Recovery of the function was assessed as evaluated by Wang *et al.* [6], where the flexion being strongest, then flexion of the finger, followed by flexion of thumb.

Results

All enrolled patients were males. Their age ranged between 16 and 28 years, with a median age of 21 years. Delay before operation ranged between 1 and 6 months, with median of 3.5 months. Other characteristics and operative data are summarized in Table 1.

Grade 3 wrist and finger flexion presented in three patients (patient with direct repair), whereas grade 2 flexion presented in seven patients (patient with graft repair). The last one patient had grade 0.

Patient with CC7 direct repair to posterior cord showed grade 3 elbow extension and grade 0 fingers and wrist extension. According to hand sensation recovery, nine patients of the group showed S2 recovery and two patients showed S1 (Table 2).

Function of the flexor carpi ulnaris muscle and flexor digitorum profundus muscles of the

Table 1 Characteristics and operative data of the studied patients

Variables	*n*=11
Age (years)	21 (16-28)
Denervation time (months)	2.5 (1-6)
Follow-up (months)	35 (25-39)
Shoulder operation	
SAN-SSN	8 (72.7)
PN-SSN	3 (27.3)
Elbow operation	
ICN-MCN	11 (100)
Mayo elbow performance score	
Good	11 (100)
Gilbert shoulder score	
Satisfactory	3 (27.3)
Fair	8 (72.7)
CC7 target	
Anterior division lower trunk	10 (91)
Posterior cord	1 (9)
Type of repair	
Nerve graft	7 (63.6)
Direct repair	4 (36.4)
BMRC scale[a]	
M2	7 (63.6)
M3	3 (27.3)

Data are expressed as *n* (%), median (range). BMRC, British Medical Research Council scale; CC7, contralateral C7; ICN-MCN, intercostal nerve-musculocutaneous nerve; PN-SSN, phrenic nerve-supra scapular nerve; SAN-SSN, spinal accessory nerve-supra scapular nerve. [a]In one patient, BMRC was M0 for wrist extension and M3 for elbow extension.

Table 2 Wrist and finger flexion and hand sensation on Medical Research Council scale

Variables	*n*=11
Wrist and finger flexion	
M3	3 (27.3)
M2	7 (63.6)
M0	1 (9.2)
Hand sensation	
S2	9 (81.8)
S1	2 (18.2)

Data expressed as *n* (%).

middle, ring, and little fingers was consistently documented, and these tended to be the strongest muscles restored.

Additionally, 10 patients achieved function of the flexor function of index finger through flexor digitorum profundus and flexor pollicis longus muscles, which were well restored (Fig. 1).

IN 10 patients, we noticed some degree of wrist and finger flexion in a duration of 16-18 months postoperative. In most of these patients, the strength did not progress, and to perform the movement, a considerable effort was needed on the opposite side (Fig. 2).

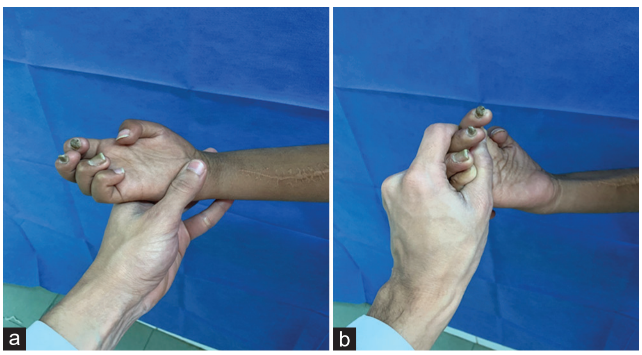
According to elbow and shoulder function in our study, we found that all 11 patients included in this study achieved good results by Elbow Mayo score system (100%), in spite of only three patients of 11 achieved satisfactory result by Gilbert shoulder system score (27.3%), whereas eight (72.7%) patients had a fair result.

Each patient described paresthesias in the distribution of root of CC7 (pulps of the thumb and index finger) immediately after surgery. This would be absent over the course of 1–6 months within surgery. In addition, some patients experienced some degree of triceps weakness but no complete deficits were noticed.

On long-term follow-up, none of the patients experienced enduring deficit in the donor limb at long-term follow-up.

This was also not objectively recorded. Only the patient's subjective experience of deficit was assessed. Moreover, following the operation, none of the patients experienced weakness on the donor site Although six patients experienced paresthesias in the thumb and index finger, this was absent within 1–6 months.

Figure 1



(a) one of our patient showing flexion of muscles of fingers (b) patient trying to hold by his hand.

Discussion

Experience with transfers of extraplexus nerve has allowed us to restore some function at the elbow and shoulder, but full regaining of this function is still elusive. To reach this end, many recent strategies have emerged regarding this issue. These have included intercostal transfers to the median nerve or to a transplanted gracilis muscle [7].

Thoracoscopic harvest of the phrenic nerve with approximation to median nerve is another available procedure. Doi *et al.* [8] used the proximal donor nerves to innervate free functioning muscle transfers by distal to proximal reconstruction. However, this technique has not been done by others.

Gu *et al.* [9] developed a great novel procedure use of the CC7 for regaining of function in the median nerve territory in 1986 [9].

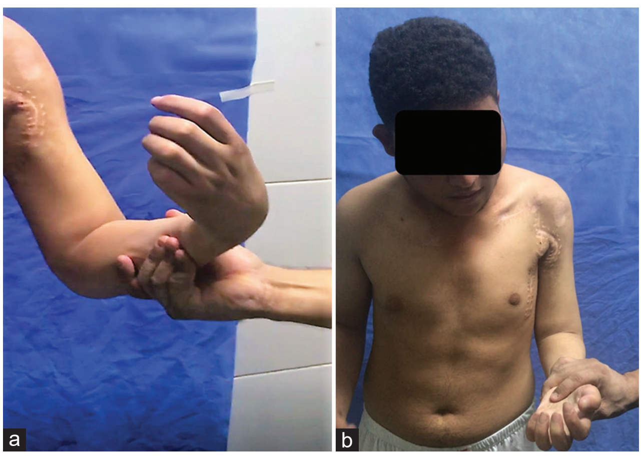
There are many limitations of this procedure: possible occurrence of defect in donor site, function takes much time to regain, and weak flexion of fingers. To restore achieved muscle power, this required forcible maneuvers with the other limb [8].

Therefore, independent use of the affected hand is not possible.

There are many factors affecting the outcome such as use of part of the root versus the entire root, different methods of harvesting the C7 root, use of nerve grafts, subcutaneous either vascularized or nonvascularized or prespinal passage, and single or multiple function needed [4].

Based on Wang *et al.* [6], they reported that to obtain better outcome of hand function, it is recommended to perform direct approximation of anterior division

Figure 2



(a) Wrist and finger flexion in patient with avulsion root. (b) The patients typically activated this function with mild adduction of the donor arm.

of the lower trunk on affected limb to the full CC7 with separation of posterior to avoid concomitant innervation of antagonist muscles.

Till now, outcomes of total arm type BPI but C5 and C6 or C5–C6–C7 trauma usually are better, with reconstruction achieving more than 80% success rate in shoulder and elbow function recovery; the reported results for total arm type BPI are much worse [10].

Main target of management of complete injury of BPI is mainly focused on neurotization and free functioning muscle transfer. Neurotization for BPI has increased in its use since 1960s. Previous published reports have showed many extraplexal neurotization ways to reconstruct functional defects after BPI, especially for shoulder and elbow reconstruction [10].

The spinal accessory nerve (SAN) has been found to successfully reconstruct shoulder function by direct neurotization on the supra scapular nerve (SSN). Inter costal nerve (ICNs) have been shown to be successfully transferred to musculocutaneous nerve (MCN) for biceps function. Narakas preferred to use the SAN to neurotize the SSN, and ICN for MCN [8].

However, intraplexal neurotization almost never has useful hand function, and these aforementioned extraplexal neurotization ways are seldom effective for reconstructing hand function for three reasons.

First, the neurotization site is far away from the target muscle over the forearm, which causes poor reinnervation of the neuromuscular junction.

Second, the axon donor nerves have insufficient numbers of myelinated fibers (1300 in each ICN and 1700 in the SAN) to match the recipient nerves (such as median nerve (MN) or ulnar nerve over the lesion site).

Third, the proximal part of the peripheral nerve (such as the MN) at trunk or cord level is a mixture of motor and sensory nerve fibers, and the regenerating axons are thus frequently misdirected compromising the results [8].

In our study, we showed a significantly lower frequency of donor site complications as we did not notice any complication other than paresthesia on the distribution of CC7, which disappeared within first 6 months. Regarding the efficacy of hand motor recovery using the CC7 method, dilemma is the choice of harvesting, whether hemi-CC7 or total CC7 [5].

Chuang and Hernon [11] harvested complete CC7 as the neurotizer that was sutured onto the vascularized ulnar nerve graft (VUNG). Their results of motor recovery in hand function after total CC7 transfer were more than 50% (M3) satisfactory.

Waikakul *et al.* [12] used hemi-CC7 and VUNG transfer to the MN for total arm type BPI in 96 patients and obtained only 21% effective finger flexion (M3). Another series by Songcharoen *et al.* [4] revealed that only 29% of the patients achieved M3 or M4 finger flexion by hemi-CC7 transfer.

Sammer *et al.* [5] found that hemi-CC7 outcome showed very dissatisfied hand function recovery, and none of their 15 patients had M3 hand grip. Terzis *et al.* [10] found outcome of a series of 56 hemi-CC7 transfers for traumatic BPI, 29 of which included transfer to the MN for hand function. Ten (34%) of these 29 patients showed useful hand motor recovery (M3).

Wang *et al.* [6] found a result of a series of 149 patient with CC7 transfer with direct repair to MCN and to lower trunk; 31/41 (75%) of them had M4–M5 finger flexion and 21/45 (39%) had M4–M5 elbow flexion function.

Bhatia *et al.* [13] found a result of a series of 22 patients with CC7 transfer to anterior division lower trunk; in the group of direct repair, 83.3% achieved M3 wrist and finger flexion in comparison with only 20% achieved M3 in graft group. They concluded that direct repair is superior to repair with graft according to their results, which is compatible with our results.

In our study, only 27.2% (3/11) of total CC7 transfers had M3 hand grip function, whereas other CC7 had less promising results (63.6% M2 hand grip). We can notice that cases which had CC7 with direct repair achieved better result than cases had CC7 repair with graft suturing.

The causes for CC7 transfer failure are attributed to atrophy of the target muscles innervated by the MN over the forearm occurs before the reinnervation technique reaches the neuromuscular junction and there is long distance between the CC7 donor nerve cooptation site and the docking site, for which the reinnervation process takes a very long time [13].

Shoulder function plays an important role in the clinical results of BPI reconstruction. Surgeons have tried to reconstruct shoulder function by various methods of neurotization procedures [3].

Sammer *et al.* [5] found CC7 as a neurotizer for shoulder function, and achieved only 23% (3/13) successful shoulder abduction (M3).

Chuang and Hernon [11] found using eight variable combinations of neurotization ways for shoulder reconstruction in patients with BPI. They found that simultaneous neurotization on the SSN and axillary achieved better outcome than just neurotization on the SSN.

In our study, we used only one neurotizer to SSN, mostly SAN, and our results was only three cases of 11 had satisfactory result based on Gilbert shoulder score. As for elbow flexion function, we found good result in elbow motor function recovery, as all of our patients showed M4–M5.

Songcharoen *et al*. [4] found accepted outcome of SA-NG-MCN neurotization for 216 patients with BPI, with 73% of M3 elbow flexion.

However, in a meta-analysis study of the English literature with 1088 nerve transfers in 27 studies, Merrell *et al*. [14] found that direct ICN transfer to the MCN had a significantly better ability to achieve M4 elbow strength than SA-NG-MCN (41 vs. 29%), which is compatible with our results.

C7 forms middle trunk, and no single muscle in the upper limb is innervated solely by C7. Therefore, dividing C7 will cause no permanent loss in sensory and motor function. Usually, the patients will undergo numbness in the fingers in the first 3 months after operation. The most affected fingers are index finger (74%), middle finger (58%), and thumb (38%) [15].

There will be temporary decrease in the grip strength but the pinch strength is not affected. It is worth pointing out that the C7 transection site should not be too distal (should never go infraclavicularly), otherwise the fibers from upper and lower trunk may be injured and permanent motor and sensory deficits may result [16].

The limitations of the current study were small number of patients and short period of follow-up, so we recommend performing future studies on large number of patients with long period of follow-up. Finally, we recommended using of CC7 as an extraplexal neurotizer in cases of traumatic brachial plexus especially when there is avulsion of all roots, while trying to achieve direct repair to obtain better functional results.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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