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Contralateral medial pectoral nerve transfer with free gracilis muscle transfer in old brachial plexus palsy

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ABSTRACT

Background: There is a very small chance of success for nerve reconstruction in patients with old total brachial plexus palsy who visit after 2 y or suffer from flail upper extremity after the failure of previous operations.
Materials and methods: For these individuals, the surgeon has to find a recipient motor nerve to perform free gracilis muscle transplantation. In this study, contralateral medial pectoral nerve from the intact side was transferred to the damaged side as a recipient nerve. Then, in the second operation, approximately 15 mo later, the free gracilis muscle transfer was performed. The gracilis muscle was removed and transferred to provide elbow and finger flexion.
Results: In a retrospective study (over 10 y), we reviewed 68 patients for whom this method had been performed. After 1 y, the results were investigated using the Medical Research Council grading system. Five patients did not participate in the study, and the muscle underwent necrosis in two patients. M3 and M4 muscle power was regained in 26 (42.6%) and 21 (34.4%) patients, respectively.
Conclusions: Contralateral pectoral nerve transfer followed by free muscle transplantation can be a good option for patients with old total brachial plexus palsy.

Introduction

Most brachial plexus injuries are in the form of the avulsion of the nerve root from the spinal cord with preganglionic injury.[1-5] These patients have a very poor prognosis of regaining acceptable performance. Total brachial plexus palsy leads to severe and chronic disorders that require timely and long-term treatment. Neural injuries cause sensory and motor disorders, muscular atrophy, and deformation. Multiple surgical operations lead to many problems and lack of cooperation. In these cases, different specialists should contribute and cooperate to achieve the best result.

Nowadays, nerve transfer[6] is usually done in acute injuries and those that have occurred in less than a year.[7-12] There is an ongoing attempt to increase the number of intra- and extraplexal donor nerves for nerve reconstruction in these patients. Traditionally, intraplexal nerves including medial pectoral, thoracodorsal (ipsilateral), and an ipsilateral C7

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nerve were used for patients with partial brachial plexus injury, while the hypoglossal, phrenic, motor nerve of cervical plexus, platysma motor branch, spinal accessory, and intercostals nerves were used for cases with pan-plexus injuries.[13-21]

However, in cases who first visit 2 y since the injury, muscles are already atrophied and nerve transfer alone is not helpful. In these cases, alternative techniques can be used. In the most complete method, a motor nerve is transferred as a recipient nerve and also an appropriate muscle as a free functional muscle to induce elbow flexion alone or synchronous elbow and finger flexion in the affected limb.[22-24]

Materials and methods

Ethical statement

This study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran (IR.SBMU.MSP.REC.1396.421). A written informed consent was obtained from all the patients for participate in study and also surgery.

Patients

From December 2003 to 2015, we reviewed 68 patients who had previous brachial injury approximately more than 2 y ago and received no treatment or had undergone an ineffective nerve transfer surgery at least 1.5 y ago by another surgeon. In all the cases, other extraplexal nerves such as ipsilateral intercostals or the accessory nerve had been used or were unusable, and there was no proper ipsilateral donor nerve. Therefore, we used the healthy nerve of the other side as the donor.

At first, the surgery that had two stages with a long interval (about 15 mo) was explained to the patients and their families. The possibility of the failure of the first or second stages of the surgery and its probable complications were completely explained.

The patients then underwent contralateral pectoral nerve transfer and, if successful, free gracilis muscle transfer was performed after 12-15 mo. All of the surgeries were performed by a team of two hand surgeons. During follow-up, the patients were visited in the clinic by hand therapists. They were under regular supervision by a permanent team of physiotherapy and occupational therapy. After 12 mo, muscle power was recorded using the British Medical Research Council and chuang modification as follows:

M5: strength against four-finger (examiner) resistance.
M4: strength against one-finger (examiner) resistance for longer than 30s.
M3: active movement against gravity.
M2: active movement with gravity eliminated.
M1: flicker (trace of contraction).
M0: no contraction.

Surgical procedure

Before any venture, the approximate distance between the medial pectoral nerve of the intact side and the injured arm was measured, which was variable (up to 45 cm) depending on the individual's body size (Fig. 1). Thus, the sural nerves had to be released for more than 45 cm. As most patients were tall and thin, we had no deficit of nerve graft length (Fig. 2). After general anesthesia in a supine position, a 4- to 7-cm-long incision was made at about 3-4 cm below the clavicle of the intact side and between the central and lateral third of the clavicle. The medial pectoral nerve was explored, and its integrity was confirmed with a nerve stimulator. The nerve was then transected. A subcutaneous tunnel was made from this incision site toward the proximal part of the paralyzed arm and a 0.0 nylon suture was passed through this tunnel so that the sural nerve could easily pass through it. Then, the distal end of the sural nerve was sutured to the transected proximal end of the medial pectoral nerve (using a 10-0 nylon suture) with the aid of loupe magnification. The proximal end of the sural nerve was then passed from the tunnel and tagged at the upper part of the paralyzed arm to facilitate its detection in the second-stage surgery. Postoperative care, particularly the restriction of the intact arm abduction for at least 3 wk, was explained to the patients. After 3 wk, both upper limbs underwent physiotherapy. Within the following 15 mo, nerve regeneration was evaluated using Tinel's sign. When the positive Tinel's sign was

Fig. 1 – Distance between the intact side of medial pectoral nerve and the injured arm. (Color version of figure is available online.)

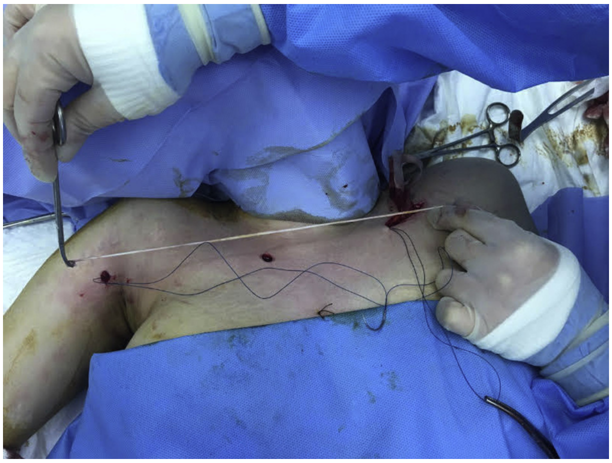

Fig. 2 – The sural nerve of the used as a nerve graft, which was released for more than 45 cm. However, in most patients who were tall and thin, there is no deficit of nerve graft length. (Color version of figure is available online.)

recorded in the proximal part of the paralyzed arm (the site of the previously tagged sural nerve graft), the patient was prepared for the second surgery.

Brachial artery angiography was performed for all patients before the first stage. At the second stage, after the incision and exploration of the previously tagged sural nerve, its 5 mm distal end was excised and sent to pathology to confirm the existence of the axonal fiber. After that, we attempted to find an appropriate branch of brachial artery and an appropriate superficial vein as the recipient. Then, the gracilis muscle was removed in a classic method[25] with appropriate nerve and vascular pedicle length. In most cases, we had to harvest the muscle completely and then tag that at every 5 cm length. The donor site was repaired by the assistant, whereas the senior surgeon worked at the recipient site. The proximal part of the muscle was fixed to the coracoids by suture-anchor, whereas, after appropriate tension (according to the previous tagged), its tendon was sutured to the four flexor digitorum profundus and the flexor pollicis longus tendons, distal to the musculotendinous junction, by nylon 2.0 Pulvertaft suture. The medial femoral circumflex artery was then anastomosed to the brachial artery (end to side) or an appropriate brachial artery branch (end to end) and its comminuting vein anastomosed with a superficial vein (such as the cephalic vein) using a 10-0 prolene with the aid of loupe magnification. Then, the end of the sural nerve was sutured to the transferred muscle motor nerve (a branch of the obturator nerve). By passing gracilis muscle's tendon below the brachioradialis muscle, this muscle acted as a pulley at the medial condyle of humerus. The limb was then splinted for 6 wk and after that the patient underwent rehabilitation by a team of physiotherapists and occupational therapists. After 3 wk, passive mobilization with stretching was started. After 6 wk, the splint was removed and active mobilization began. When the complete range of motion was achieved, weight-bearing programs were started for the patients.[26] Within 1 y after surgery, the patients were regularly visited and their muscle power was measured and recorded (each 3 mo).

Data analysis

Data were analyzed in SPSS software (ver. 23.0) using the chi-squared test at the significance level of <0.05.

Results

Overall, 68 patients, comprising 64 (94.1%) men and 4 (5.9%) women, underwent this operation from December 2003 to 2015. The average age of the patients was 22.95 ± 5.35 y (ranging from 15 to 48 y). The brachial plexus was involved on the right and left sides in 25 (36.8%) and 43 (63.2%) patients, respectively. The mean length of the sural nerve grafts was 44.4 ± 2.2 cm.

In two patients, we had free flap failure. This was probably due to technical problems, but we observed arterial thrombosis in one case and atherosclerotic arteries in the other. Five patients withdrew from the second phase of the surgery. After 12 mo, 61 patients completely participated in our study. According to the British Medical Research Council scale and chuang modification, 47 (77%) patients regained M4 and M3 muscle power (Table). Forty-two patients were capable of finger flexion between 35° and 60°, and 31 patients were able to finger flexion (Fig. 3).

Discussion

Ikuta *et al.* were the first to use free-functioning muscle transfer (FFMT) in brachial plexus reconstruction for elbow flexion in children with delayed referrals.[26] Today, FFMT is used in many cases of brachial plexus injury, particularly in cases with delayed referrals or where previous surgeries have failed.

Table – Postoperative (1 y) gain of function results based on British Medical Research Council (MRC) scale and chuang modification.

Genus	M0, No. (%)	M1, No. (%)	M2, No. (%)	M3, No. (%)	M4, No. (%)	Total, No. (%)
Male	2 (3.3)	7 (11.5)	3 (4.9)	24 (39.3)	21 (34.4)	57 (93.4)
Female	0 (0.0)	0 (0.0)	2 (3.3)	2 (3.3)	0 (0.0)	4 (6.6)
Total	2 (3.3)	7 (11.5)	5 (8.2)	26 (42.6)	21 (34.4)	61 (100)

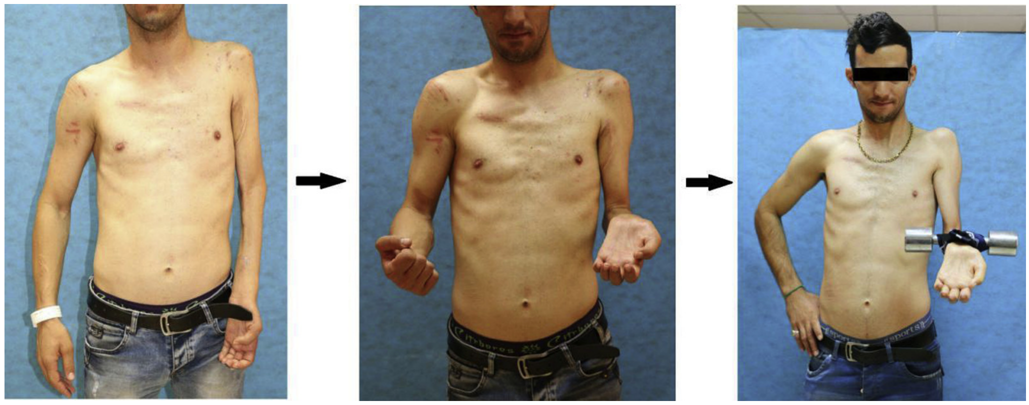

Fig. 3 – The elbow and finger flexion after treatment. (Color version of figure is available online.)

Moreover, Manktelow *et al.*[24] and Doi *et al.*[26] conducted extensive research on fundamental science, anatomy, and FFMT.

There is an ongoing attempt and research to find more extraplexal nerves for nerve transfer. For the first time, Gu *et al.* used the C7 root of the intact side[27] and Gilbert (1992) performed contralateral pectoral nerve transfer.[28] In addition, in a study on rats, Bertelli *et al.*[29] reported a 90% success rate using this method. In this study, it was shown that the contralateral limb could be used as a source for nerve transfer. They reported that the radial nerve of the intact organ was transected, and the distal end was sutured to the medial cord of the paralyzed side, and then a tendon transfer was performed in the intact hand.[28] Cross-pectoral nerve transfer was then performed for elbow flexion.[29] Hosseinian *et al.*[30] used this method for elbow and finger flexion without thumb flexion. Nevertheless, the thumb underwent osteoarthritis in the opposition position. We used our technique for elbow and finger flexion and thumb flexion simultaneously, without observing any sign of osteoarthritis in our patients.

In old brachial plexus injury, denervated muscles become atrophic and nerve transfer or nerve graft is not effective. Consequently, FFMT is the only option for functional restoration. This can be carried out in one or two stages depending on the proximity of the available donor motor nerve.

Ipsilateral extraplexus nerve transfer has widely been used to reconstruct elbow and finger flexion. Intercostal and spinal accessory nerves are the most commonly used donors.[31] When there is no intraplexal or ipsilateral extraplexal donor nerve available for reconstruction or there is contraindication for their use, for example, in cases with respiratory or shoulder comorbidity, we have to use the intraplexal nerve of the contralateral side. The selection of donor nerves is limited especially in old brachial plexus injury with multiple previous surgeries or in patients who require multiple nerves to make different functions such as shoulder abduction, elbow flexion, elbow extension, and wrist and finger flexion. Therefore, it is possible to use the extraplexal donor nerves of the opposite side.

In this study, in the cases of old (or late-presenting) panplexus injuries, as the ipsilateral donor nerve was not available, we performed a two-stage procedure using a banked sural nerve sutured to the contralateral medial pectoral nerve with free gracilis muscle transfer. The first advantage of our method is that there is no considerable donor morbidity. Furthermore, despite the long length of the sural nerve and because of its small diameter, there is no need for vascularized sural nerve transfer.[32,33]

This treatment may have certain limitations. First, a two-stage surgery procedure is required with a relatively long interval that can lead to stiffness or limitation of motion in joints. Second, the length of the sural nerve may be short. In these cases, two nerve grafts are required (although this problem was not observed in our patients). Third, fibrosis and adhesion may be seen in the transferred muscle that may necessitate surgical tenolysis. Fourth, the muscle tendon may be short and unable to reach the tendinous muscular junctions of the flexor digitorum profundus, necessitating tendon graft.

Conclusion

In summary, in old brachial plexus injuries with total palsy when no nerve on the affected side is available for the free transmission of muscle, the extraplexal nerve of the other side combined with sural graft can be successfully used as an alternative approach.

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Authors' contributions: Study design was contributed by M.Y. and A. R.; experimental study was carried out by H.M. and S.N.; data were analyzed by H.M, and S.N.; article was written M.Y., H.M., and A.R.

Disclosure

The authors reported no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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