Restoration of Elbow Flexion in Traumatic Upper Brachial Plexus Palsy in Adults: Outcome with Intraplexus Distal Nerve Transfers in 78 Patients

Restauração da flexão do cotovelo na paralisia traumática superior do plexo braquial em adultos: resultado com transferências intraplexuais distais em 78 pacientes

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Abstract

Objective To present the functional outcomes of distal nerve transfer techniques for restoration of elbow flexion after upper brachial plexus injury.

Method The files of 78 adult patients with C5, C6, ± C7 lesions were reviewed. The attempt to restore elbow flexion was made by intraplexus distal nerve transfers using a fascicle of the ulnar nerve (group A, $n = 43$), or a fascicle of the median nerve (group B, $n = 16$) or a combination of both (group C, $n = 19$). The result of the treatment was defined based on the British Medical Research Council grading system: muscle strength $<$ M3 was considered a poor result.

Results The global incidence of good/excellent results with these nerve transfers was 80.7%, and for different surgical techniques (groups A, B, C), it was 86%, 56.2% and 100% respectively. Patients submitted to ulnar nerve transfer or double transfer (ulnar + median fascicles transfer) had a better outcome than those submitted to median nerve transfer alone ($p < 0.05$). There was no significant difference between the outcome of ulnar transfer and double transfer.

Conclusion In cases of traumatic injury of the upper brachial plexus, good and excelent results in the restoration of elbow flexion can be obtained using distal nerve transfers.

Keywords
- brachial plexus palsy
- distal nerve transfers
- elbow flexion restoration

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Resumo

Objetivo Apresentar os resultados funcionais das técnicas de transferências de nervos para a restauração da flexão do cotovelo em lesões traumáticas superiores do plexo braquial.

Método Foram revisados os arquivos de 78 pacientes adultos com lesões de C5, C6, ± C7. Na tentativa de restaurar a flexão do cotovelo, foram realizadas transferência de nervos intraplexuais distais utilizando um fascículo do nervo ulnar (grupo A, $n = 43$), ou um fascículo do nervo mediano (grupo B, $n = 16$) ou uma combinação de ambos (grupo C, $n = 19$). Os resultados do tratamento com diferentes tipos de transferências de nervos foram definidos com base no sistema de graduação do British Medical Research Council: força muscular < M3 foi considerado como mau resultado.

Resultados A incidência global de bons/excelentes resultados com essas transferências de nervos foi de 80,7% e para as diferentes técnicas cirúrgicas (grupos A, B, C), foi de 86%, 56,2% e 100%, respectivamente. Pacientes submetidos à transferência do nervo ulnar ou à dupla transferência (transferência de fascículos ulnar + mediano) alcançaram melhor resultado que aqueles submetidos à transferência isolada de fascículo do nervo mediano ($p < 0,05$). Não houve diferença estatística significativa entre os resultados da transferência de fascículo do nervo ulnar e a transferência dupla.

Conclusão A transferência distal de nervos pode produzir resultados bons e excelentes na restauração da flexão do cotovelo em pacientes com lesão traumática do plexo braquial superior.

Palavras-chave
- paralisia do plexo braquial
- transferências distal de nervos
- restauração da flexão do cotovelo

Introduction

Restoration of elbow flexion is usually the first priority in the surgical treatment of traumatic brachial plexus injuries in adults.[1–3] The aim of the surgical reconstruction is to restore biceps muscle function and sometimes brachial muscle function as well, through musculocutaneous reinnervation. Several operative procedures have been described with this purpose, including the direct repair with nerve grafting using one or more nonavulsed roots as donors of regenerating axons, or nerve transfers using uninvolved adjacent nerves originating or not from the plexus. Despite the extensive experience gained in the last decades with those techniques, there is no consensus about the best strategy to restore elbow flexion. Recently, distal nerve transfers, initially indicated only for nerve root avulsion injuries, became popular for the treatment of postganglionic nerve injuries as well, but there is no prospective, randomized controlled trials comparing reconstruction with grafts or nerve transfers in the literature. The objective of this retrospective study is to present the outcomes and compare the results of different techniques of distal nerve transfer for restoration of elbow flexion in traumatic upper brachial plexus lesions in adults.

Materials and Methods

Over an eight-year period (from January 2004 to January 2012), 406 patients with closed traumatic brachial plexus injuries were operated in the Peripheral Nerve Surgery Unit of the Division of Functional Neurosurgery of the Medical School of Universidade de São Paulo, Brazil. Cases of complete brachial plexus lesions, with late referral (more than 1 year after the lesion), with insufficient follow-up (less than 18 months), and cases lost during the follow-up were discarded. Patients submitted to nerve grafting, to neurolysis, and those submitted to late secondary procedures (muscle/tendon transfers) were discarded as well. A total of 78 patients with C5, C6, ± C7 lesions remained for comparative retrospective analysis. The typical lesion was a closed traction brachial plexus injury that failed to show progressive spontaneous improvement. Prior to the surgical reconstruction, the patients underwent a physical examination, electrodiagnostic studies, imaging studies (computed tomography myelography or magnetic resonance imaging) and intraoperative observation.The nerve transfers were performed when the C5 and C6 roots had been avulsed, or when the patient was referred more than 8 months after the injury. The time interval from the injury to brachial plexus reconstruction was always shorter than 1 year, and the surgeries were grouped as early (less than 6 months) and overdue (more than 6 months).

The attempt to restore elbow flexion was made by intraplexus distal nerve transfers using a fascicle of the ulnar nerve (group A) (►**Fig. 1**), or a fascicle of the median nerve (group B) (►**Fig. 2**) or a combination of both techniques (fascicles of median and ulnar nerves; group C) (►**Fig. 3**).

Postoperatively, the affected upper limb was immobilized in internal rotation with the elbow flexed at ninety degrees for three weeks, and after this time the patients were referred to rehabilitation. The postoperative follow-up consisted of clinical evaluations every 6 months after surgery, for a period of at least 18 months. In the final clinical evaluation, the result of the treatment was defined based on the British

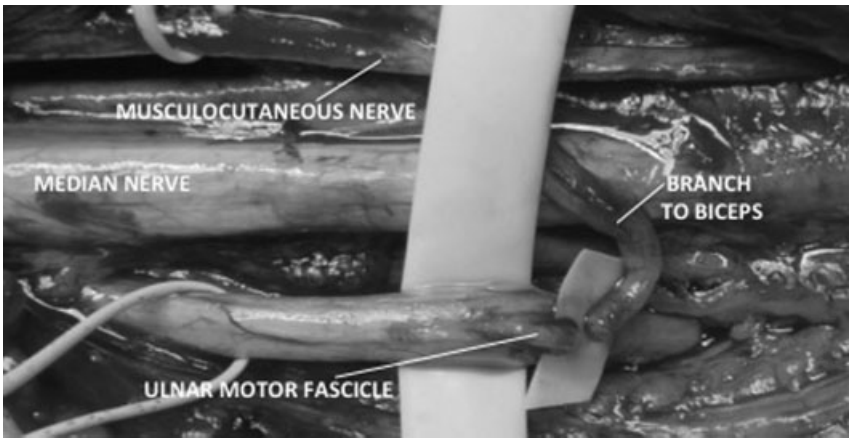

Fig. 1 Operative view, left arm, medial surface. Transfer of a motor fascicle of the ulnar nerve, usually related to the flexor carpi ulnaris muscle, to the motor branch of the musculocutaneous nerve of the biceps muscle.

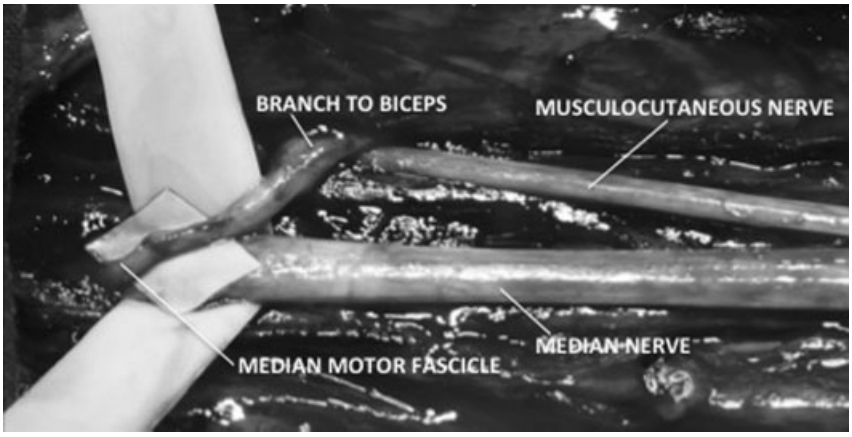

Fig. 2 Operative view, left arm, medial surface. Transfer of a motor fascicle of the median nerve, usually related to the flexor carpi radialis muscle, to the motor branch of the musculocutaneous nerve of the biceps muscle.

Medical Research Council (BMRC) grading system (which goes from M0 to M5). Elbow flexion strength $\geq$ M3 (contraction with active movement of normal amplitude against gravity) was considered a good result. Muscle strength $<$ M3 was considered a poor result. The final outcome of the three treatment groups was compared.

The statistical analysis for group comparison was performed using the Fisher exact test. The Mann-Whitney U test was applied for the comparison of the surgical timing between patients with good and bad outcomes. The differences between the groups were considered significant when $p < 0.05$.

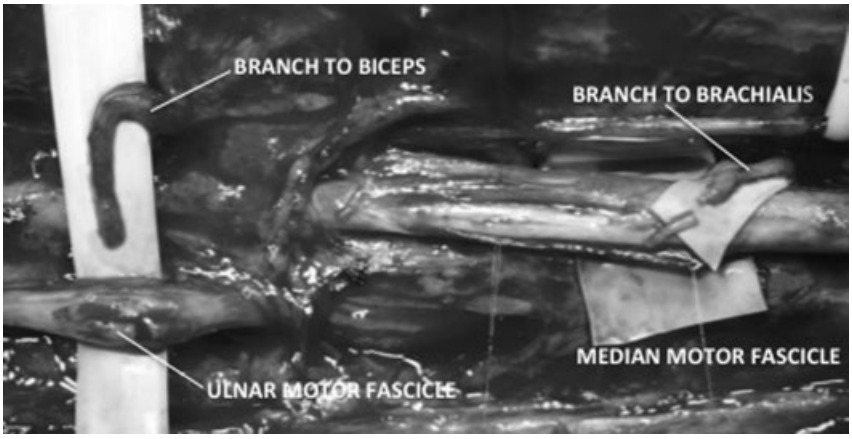

Fig. 3 Operative view, left arm, medial surface. Double transfer of a motor fascicle of the ulnar nerve to the motor branch of the musculocutaneous nerve of the biceps muscle, and of a motor fascicle of the median nerve to the motor branch of the meusculocutaneous nerve of the brachialis muscle.

Results

Most of the patients were male (93.4%) with an average age of 28.7 years (range: 18 to 67 years). Motorcycle accidents were responsible for 79% of the injuries.

The donor nerves for intraplexus nerve transfers (78 patients; ►**Table 1**) included a fascicle of the ulnar nerve (group A: 43 patients), a fascicle of the median nerve (group B: 16 patients), and a combination of fascicles from the ulnar and median nerves (group C: 19 patients). The global incidence of good/excellent results with these nerve transfers was of 80.7%. For different surgical techniques (groups A, B and C) the percentage of good/excelente results was of 86%, 56.2% and 100% respectively. Patients submitted to ulnar nerve transfer or double transfer had a better outcome than those submitted to median nerve transfer alone ($p < 0.05$). There was no significant difference between the outcome of groups A and C. Patients with good outcomes were operated sooner than those with bad outcomes ($p < 0.05$), but there was no statistical difference regarding surgical timing among the groups.

Discussion

Adult brachial plexus paralysis is caused mainly by high velocity motor vehicle accidents and involves primarily young male adults.[4] The socioeconomic impact of these injuries is usually high because the patients have to face a prolonged period of rehabilitation, and sometimes the final outcome is permanent paralysis. The functional outcome achieved with the surgical treatment of these patients has improved over the last decades, and the restoration of elbow flexion, an important function for daily activities, is the highest priority in the reconstruction. In our series, the reinnervation of the biceps muscle through the reconstruction of the musculocutaneous nerve was performed at the same time as the reinnervation of other targets, aiming to achieve as much of the entire plexus reconstruction as possible. The strategy we used to reconstruct the musculocutaneous nerve included the primary grafting and the transfer of intraplexus and extraplexus nerves. The choice of donor nerves for transfers relied on the severity of the injury, the availability of motor donors, and surgeon preference. In partial lesions, primary grafting and intraplexus nerve transfers were used for the reconstruction of the musculocutaneous nerve. In complete lesions, primary grafting and extraplexus transfers were performed. The great boost in the surgical treatment of traumatic brachial plexus lesions came after the introduction of primary grafting with microsurgical techniques.[2,5,6] Usually, a full exploration of the supraclavicular part of the plexus is performed to establish the extent and severity of the injury, and if any nerve roots are suitable for nerve graft repair. Even in complete clinical brachial palsies at least one root is available as a donor in many cases. The nerve grafts are usually coapted proximally to the C5 and/or C6 roots, and the distal coaptation can be in the upper trunk, the anterior division of the upper trunk, the lateral cord, or the musculocutaneous nerve itself, but the results with this approach are far from satisfactory. Data from the literature demonstrates that good/excellent results with primary grafting could be achieved in 10.4 to 92% of the patients (average = 66.2%).[7–19] In the same period in which the data related to the intraplexus nerve transfers was collected from our series, we performed nerve grafting in 38 patients, connecting C5, C6 or both nerve roots to the upper trunk (2 cases), the upper trunk anterior division (24 cases), the lateral cord (3 cases), or directly to the musculocutaneous nerve (9 cases). Altogether, 23 patients (60.5%) achieved M3 or a higher degree of elbow flexion. Altough some authors[6,20–22] do prefer intraplexus donors (roots or trunks) for neurotization of the musculocutaneous nerve, the unsatisfactory results, the absence of a prospective, randomized clinical trial comparing nerve transfers versus nerve grafts, and a recent review demonstrating that in upper brachial plexus injuries nerve transfers are more successful for the restoration of elbow flexion than nerve grafting[23] motivated us to review our intraplexus transfer results.

The transfer of an ulnar nerve fascicle (usually related to the flexor carpi ulnaris muscle) to the motor branch of the musculocutaneous nerve of the biceps muscle was described by Oberlin et al,[24] and presents good/excellent results (M3 or higher) in the literature, ranging from 61.1 to 100% (average = 83.5%).[9,18,24–37] We used this technique in 43

Table 1 Results of intraplexus nerve transfers

Results of Intraplexus Nerve Transfers					
Donor	*Target*	*Cases*	*Good/excellent results (M3-M4)*		
			Total	*Surgery < 180 days before the lesion*	*Surgery >180 days after the lesion*
Ulnar motor fascicle	motor branch of the musculocutaneous nerve of the biceps muscle	43	37 cases/86%	17 cases/100%	20 cases/76.9%
Median motor fascicle	motor branch of the musculocutaneous nerve of the biceps muscle	16	9 cases/56.2%	5 cases/62.5%	4 cases/36.3%
Ulnar/median motor fascicles	motor branches of the musculocutaneous nerve of the biceps and brachialis muscles	19	19 cases/100%	6 cases/100%	13 cases/100%

patients, obtaining good/excellent results (M3 or higher) in 37 (86%) of them. The reinnervation of the biceps muscle using a fascicle of the median nerve (usually related to the flexor carpi radialis muscle) was described by Hou and Xu[38] in 2002 and by Sungpet et al[39] in 2003. The reported outcomes with this technique vary from 63.6 to 100% (average = 86.7%) of good/excellent results.[27,38–40] Although some authors prefer this transfer to the procedure described by Oberlin because of the larger diameter of the median nerve and its proximity to the musculocutaneous nerve,[40] the incidence of good/excellent results in our series (9 patients out of 16; 56.2%) was inferior to the results using an ulnar fascicle. In an attempt to improve the results of the Oberlin procedure, a concomitant transfer of a fascicle of the median nerve to the motor branch of the musculocutaneous nerve of the brachialis muscle was introduced in 2003 by Tung et al.[41] The published outcome of this technique ranges from 75 to 100% of good/excellent results (average = 93.4%).[25,26,30,41–45] Two recent publications[26,46] demonstrated that the intensity of the elbow flexion did not differ significantly between groups of patients treated with single (biceps) and double (biceps and brachial) muscle innervations; however, we achieved 100% of good/excellent results with the double transfer in this series. Although the results were better than median nerve transfers, there was no significant difference between double transfers and isolated ulnar nerve transfers.

Several factors may be related to better results in intraplexual distal nerve transfers when comparing them with supraclavicular brachial plexus grafting: two suture junctions in autogenous nerve grafting versus single suture junction in nerve transfer; in intraplexus nerve transfers, the coaptation between the donor and the target nerves is closer to the muscle to be innervated than in nerve grafting; grafts usually are not necessary in intraplexus transfers; albeit injured, the nerve transfer recipient is vascularized, while grafts are non-vascularized; the operative site is usually more fibrotic in the grafting procedure; in intraplexus nerve transfers, combinations of similarly behaving neuromuscular units facilitating the cortical adaptation are generally used.[47,48]

The present study has some limitations. It is a retrospective series, and the number of patients is relatively small. Prospective randomized trials should certainly provide more definitive answers.

Conclusion

Our data showed acceptable outcomes, comparable to previously reported results in the literature. At the moment, intraplexus distal nerve transfers are our prefered strategy for the reinnervation of the biceps and sometimes the brachialis muscle as well.

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