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Neurotization in the Treatment of Brachial Plexus Root Avulsion Injuries: A Case Report and Review of the Literature

Brakial Pleksusun Kök Avulsiyonu Şeklindeki Yaralanmalarının Tedavisinde Nörotizasyon: Bir Olgu Sunumu ve Literatürün Gözden Geçirilmesi

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ABSTRACT

INTRODUCTION: Brachial plexus root avulsion injuries cannot be repaired by neurorrhaphy or nerve grafting. There is no possibility of spontaneous recovery and these injuries occur most often in individuals who are in their productive period. At present, the best surgical treatment option for brachial root avulsion injury is neurotization.

OBJECTIVE: To describe the importance of neurotization in the treatment of brachial plexus root avulsion injury in view of the literature.

CASE: A thirty-year-old male patient, who had suffered a traffic accident 6 months ago, was referred to our clinic because of ongoing severe pain refractory to medical treatment and weakness of the left arm. A complete brachial plexus lesion in the form of a root avulsion was diagnosed after neurological and radiological evaluation. Neuroneural neurotization was performed. The spinal accessory nerve, phrenic nerve and cervical plexus were used as donor nerves while the sural nerve was the choice as inter-graft material. In this patient with adult type brachial plexus injury, pain decreased in the early post-surgical period and there was no change in neurological examination at 6 months follow-up.

CONCLUSION: One of the greatest problems for peripheral nerve surgeons is treating functional loss due to brachial plexus injuries. It takes a long time to regain lost function after neurotization in brachial plexus root avulsion injuries. Physical therapy and rehabilitation are very important in the postoperative period. It should always be kept in mind that the acquirement of even some function is important for the patient.

KEY WORDS: Brachial plexus injuries, Root avulsion, Neurotization

ÖZ

GİRİŞ: Brakial pleksus kök avulsiyon yaralanmalarının en önemli özellikleri; spontan iyileşme şansının olmaması, nörorafi veya sinir greftleme gibi teknikler ile bu lezyonların onarılamaması ve çok sıklıkla bu tür yaralanmaların genç yaşta gözlenmesidir. Günümüzde brakial peksus kök avulsiyon yaralanmalarının tedavisinde nörotizasyon en önemli seçenek olarak düşünülmektedir.

AMAÇ: Brakial pleksus kök avulsiyon yaralanmalarında nörotizasyonun yeri ve önemini literatür derlemesi ile birlikte sunmaktır.

OLGU: Otuz yaşında erkek hasta, geçirdiği trafik kazası sonrası 6. ayda sol kolunda medikal tedaviye cevap vermeyen şiddetli ağrı ve sebat eden güçsüzlük nedeniyle dış merkezden kliniğimize refere edildi. Nörolojik muayene ve radyolojik incelemelerinde komplet brakial pleksus lezyonunun, kök avulsiyonları şeklinde olduğu tespit edildi. Nöronöral nörotizasyon yapıldı. Donör sinir olarak spinal aksesuar sinir, frenik sinir, ve servikal pleksus; ara greftleme için ise sural sinir kullanıldı. Cerrahi sonrası erken dönemde ağrısı geçen erişkin tip brakial pleksus yaralanmalı hastada, cerrahi sonrası 6 aylık takipte nörolojik muayenede değişiklik olmadı.

SONUÇ: Brakial pleksus yaralanmasına bağlı fonksiyonel kayıpların hafifletilmesi veya ortadan kaldırılması, tedavi sorumluluğunu üzerine alan periferik sinir cerrahlarının en büyük sorunlarındandır. Brakial pleksus kök avulsiyon yaralanmalarında nörotizasyon ile fonksiyonların tekrar kazanılması fizik tedavi ve rehabilitasyon ile birlikte uzun bir süreç içerisinde gerçekleşmektedir. Ancak elde edilecek fonksiyonel en küçük kazanımın bile hasta açısından önemli olduğunu unutmamak gereklidir.

ANAHTAR SÖZCÜKLER: Brakial pleksus yaralanmaları, Kök avulsiyon, Nörotizasyon

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INTRODUCTION

It has been observed gradually to be increasing improvement and development in the surgical treatment of brachial plexus injuries for the last 2-3 decades (2,7,10,15,16,17,19,25,26,27,28,33,36,37,38). However, the functional outcome and the chances of improvement by surgery following these injuries is far from being satisfactory from an objective point of view and not yet promising as expected. Surgical treatment choices of severe brachial plexus injuries presenting with root avulsions caused by motorcycle accidents are fairly limited. Brachial plexus root avulsion injuries has become a great challenge to peripheral nerve surgeons because this type injuries particularly cannot be repaired by the techniques has limited use and low success rate as neurorrhaphy or nerve grefting and has no possibility of spontaneous recovery. Neurotization seems to be the only alternative method of surgical treatment of a brachial plexus root avulsion (2,7,16,17,19,25,27,28,33,36,37,38).

We report a patient with brachial plexus root avulsion injury treated with neurotization and discuss the treatment in accordance with the literature.

CASE REPORT

A 30-year-old man, who had suffered a traffic accident 6 months ago, was referred to our hospital with a complaint of severe pain refractory to medical treatment and complete motor weakness of his left upper extremity. His neurological examination revealed complete motor, sensory and deep tendon reflex loss and left-sided Horner syndrome. His left arm was swinging like a pendulum. The X-Ray evaluation showed a left clavicle and C7-T1 transverse process fracture. The phrenic nerve was functioning on the fluoroscopy study. Traditional myelography using metrizamide contrast revealed the presence of a pseudomeningocele at the level of the left C5, C6, C7, and C8 nerve roots (Figure 1A and 1B). Cervical MRI and computed tomography, performed with and without a contrast agent, showed empty-appearing root sleeves, a shift of the cord in one direction or another away from the midline, and foraminal and extraforaminal pseudomeningocele associated with avulsion of the corresponding root (Figure 2A and 2B). Electrophysiological work-up at the fourth month showed complete brachial plexus denervation. Preoperative respiratory capacity was normal. His neurologic, electrophysiologic, and radiological evaluation revealed a complete brachial plexus lesion in the form of root avulsion. The patient was operated on for exploration. During surgical intervention, all the nerve roots forming the brachial plexus were explored up to all neural foraminas. It was shown that the left C8 and T1 nerve roots broke off intraforaminally and the left C5, C6, and C7 nerve roots extraforaminally (Figure 3). Neuroneural neurotization was performed after nerve neurolysis (Figure 4). The spinal accessory nerve, phrenic nerve and cervical plexus were used as donor nerves while the sural nerve was the choice for intergrafting. In this patient with adult type brachial plexus injury, pain was relieved in the early post-surgical period and there was no change in the neurological examination on 6 months follow-up.

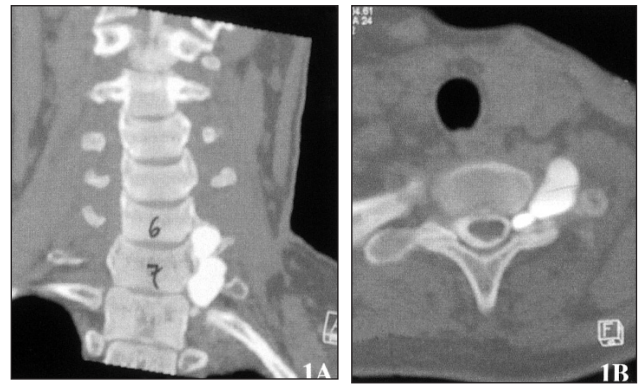

Figure 1: Coronal (**A**) and axial (**B**) computed tomography of the cervical spine performed with contrast agents showed the presence of pseudomeningoceles at the level of the left C5, C6, C7, C8, T1 nerve roots

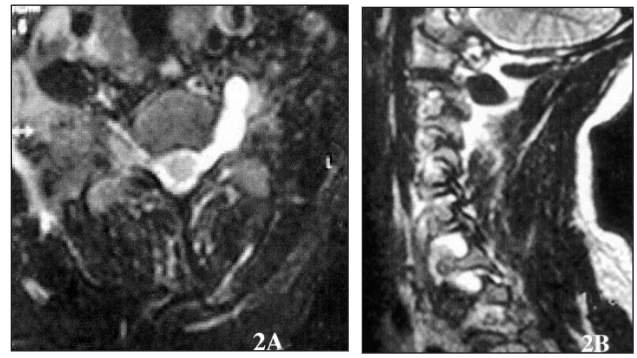

Figure 2: T2-weighted axial (**A**) and sagittal (**B**) cervical MRI revealed foraminal and extraforaminal pseudomeningocele and a shift of the cord in one direction or another away from the midline

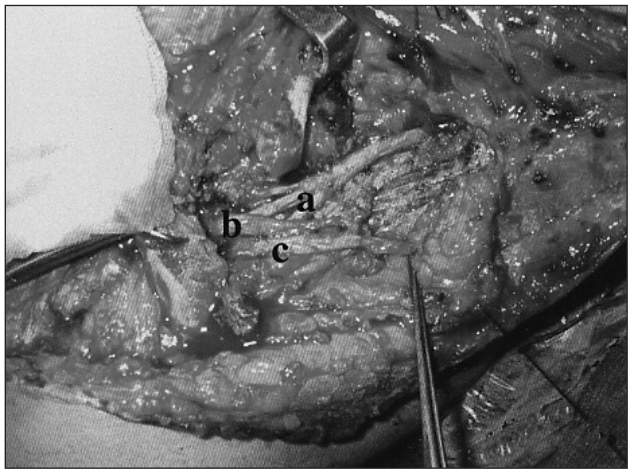

Figure 3: It was shown peroperatively that the left C8 and T1 nerve roots broke off intraforaminally and the left C5, C6, and C7 extraforaminally (a, b, c: posterior and medial cord segments of the brachial plexus)

Figure 4: Spinal accessory nerve, phrenic nerve and cervical plexus used as donour nerves while sural nerve was the choice of intergrefting. (neuroneural neurotizations (a: phrenic nerve b: cervical plexus c: spinal accessory nerve)

DISCUSSION

Repairing the brachial plexus by surgery has been a topic of interest for peripheral nerve surgeons for the last century. Several surgical techniques have been used for the treatment of brachial plexus root avulsion injuries. The incidence of brachial plexus injuries presenting with root avulsion has gradually increased over the last three decades (10). Unsuccessful outcomes related to neurorrhaphy and nerve grafting techniques in the treatment of this type of injury have led to the development of new techniques. Neurotization has recently been accepted as an effective technique for the treatment of brachial plexus root avulsion injuries to reconstitute the continuity of the nerve root with the spinal cord (7,8). Neurotization refers to the reinnervation of the denervated motor or sensory end-organ. Neurotization can be performed as musculomuscular, cutaneocutaneous, neuroneural, neuromuscular or neurocutaneous. Neuromuscular and neuroneural techniques have been preferred in the treatment of brachial plexus root avulsion injuries until now.

Attempts at neuroneural neurotization were first reported in 1873 by Letievant et al. who performed an end-to-side anostomosis between the injured and healthy nerve (33). The first attempt at intraplexal neurotization by implanting the distal stump of the avulsed C5 spinal nerve root into the healthy C6 spinal nerve root was described by Haris and Low in 1903 (33). Tuttle (33) described the first attempt of extraplexal neurotization between the brachial plexus and deep cervical plexus in 1913. Since then, different types of neuroneural neurotization have been used. Successful intercostal neurotization was first performed by Yeoman and Seddon (39). This neurotization technique was modified by Tsuyama, Hara and Nagona. Later, the motor branch of the deep cervical plexus (4,5), spinal accesory nerve (23,24,31,32), phrenic nerve and contralateral C7 nerve (12,13) was used as a donor for motor neurotization of brachial plexus nerve root avulsion injuries.

Neurotizations are considered to be the last choice for restoring function to the injured brachial plexus that could not be achieved with other treatment modalities (33). Several factors should be considered in an attempt of neurotization. Several important factors such as the inborn properties of both donor and recipient tissues, the surgical technique, and in particular the donor nerve to be harvested determe the success rate of neurotization. Neurotization means sacrificing functional donor nerve in favor of nonfunctional tissue, either nerve or muscle. The gain in function must therefore be more important than the functional loss. Motor and sensory nerves should be matched to motor or sensory nerve respectively to achieve the best results. Some donor nerves such as the intercostal nerves have both sensory and motor functions. In order to avoid mismatch and provide connection to true nerve, intraoperative histochemical techniques and electrophysiological stimulations should be used

(9,34). Moreover, multiple recipient nerves with different functions should not be neurotized to single donor nerve, and fasciculi types and numbers, and in particular nerves, should be similar to the donor for a favorable outcome (23,24). The inadequacy of donor fascicles will jeopardize the functional result of the reinnervated organ. Brachial plexus injuries should be completely evaluated and explored. It may be necessary to explore up to the intraforaminal level.

Neurotization distal to the lesion is more successful than proximal neurotization (33). Moreover, motor neurotization should be reserved for simple motor functions like shoulder elevation, and not for fine motor skills like hand and finger activity because most of the available donor nerves control relatively simple functions of shoulder elevation or thorax expansion (19,33).

Major donor nerves used for neurotization are the spinal accessory nerve, intercostal nerves, the phrenic nerve, nerve roots in the brachial plexus, the cervical plexus, the long thoracic nerve and the contralateral C7 nerve. In the presented case, extraplexal neurotization was performed through the spinal accesory nerve, the phrenic nerve and branches of the cervical plexus. The sural nerves were used for intergrafting. The spinal accessory nerve can be transferred to a number of different recipients. To achieve shoulder abduction, flexion and external rotation, the musculocutaneous, axillary and suprascapular nerves have been successfully transferred through the spinal accessory nerve. Among these nerves, the suprascapular nerve has been shown to be the best recipient for spinal accessory neurotization. The spinal accessory nerve can also be directly transferred to the suprascapular nerve without using an intermediate nerve graft. However intergrafting is mandatory for musculocutaneous nerve neurotization (1,25,26,27). The musculocutaneous nerve has both motor fibers and sensory fibers within the same recipient. Donor motor fibers from the spinal accessory nerve are partly distributed to sensory receptors through the lateral cutaneous nerve of the forearm. A much longer intermediate graft between the spinal accessory nerve and motor branch of the musculocutaneous nerve should be used or direct neuromuscular neurotization of the lateral cutaneous nerve of the forearm to biceps muscle should be performed (3). Studies on neurotizations of the spinal accessory nerve to the radial and the median nerve have reported unsatisfactory results. As used in the presented case, intercostal nerves contain both sensory and motor fibers and each intercostal nerve carries a different amount of sensory and motor fibers individually (11,25). The first and second intercostal nerves should not be used for motor neurotization as they are partially located in the plexus and because of the features of the second intercostal nerve as a mainly sensory nerve. On the other hand, the lower intercostal nerves innervate the abdominal and intercostal muscles. The third, fourth, fifth and sixth intercostal nerves, with an increasing number of motor fibers, can be effectively used as donors for motor neurotization. In the author's experience, the most practical usage and the best outcomes are with the musculocutaneous nerves regardless of the donor nerves (25,38). Motor recovery in the biceps muscle needs approximately 12 months and biceps function continues to synchronize with inspiration and particularly with expiration during the first 2 years after operation. Voluntary contraction of the muscle develops for up to 3 years but there will still be involuntary movements following sneezing or coughing (20,35). Outcomes regarding transfer of intercostal nerves to other recipients are not favorable as mentioned. The phrenic nerve, innervating the diaphragm, diaphragmatic pleura, peritoneum and pericardium, is also used for neurotization, but diaphragmatic and pulmonary functions should be evaluated before harvesting the phrenic nerve. In case of acute brachial plexus injury, especially when there is accompanying severe chest trauma and rib fractures, pulmonary function must be carefully evaluated (12,16,33). Even if diaphragmatic movement is still intact, the use of the phrenic nerve in these patients will greatly jeopardize pulmonary function because respiratory movement depends mainly on the diaphragm. In the presented case and 35 other reported cases, no postoperative pulmonary dysfunction or complications have been shown (33). 75% of the cases had decreased respiratory capacity that gradually recovered after 8 months (33). The suprascapular nerve is the best recipient for phrenic neurotization. This technique can generally be performed without an interposition nerve graft. Favorable outcomes may be achieved with musculocutanous and axillary nerve neurotizations

(12). In complete brachial plexus paralysis with avulsion of the C6-T1, C7-T1 roots, extraforaminally ruptured C5 or C5 and C6 nerve roots can be used as donors for neurotization. Motor and sensory fibers of the cervical plexus, originating from C1 to C4, can be used for suprascapular, musculocutaneous and median nerve neurotizations (5). The contralateral C7 nerve root has also been used in reported cases. The number of C7 nerve root fibers are far greater than the number of fibers from all other extraplexal donors together. Destroying the C7 nerve root fibers also result in minimal neurological deficits (6). The C7 nerve root can particularly be used when no other nerve can be employed for the neurotization procedures (2,12,13). In the author's experience, neurotizations of the injured median, radial and musculocutaneous nerves with C7 roots have provided good outcomes. Neurotization series of experienced authors have demonstrated a high rate of good outcomes in the years following the procedure (14,18,21,22,29,30).

Treatment of brachial plexus root avulsion injuries should also be with postoperative physical therapy and rehabilitation to achieve a favorable functional outcome. Physiotherapy, kinesiotherapy, active splinting and electrical stimulation play an active role during the convalescence period. Regeneration should be evaluated regularly and reconstructive surgery kept in mind in case of insufficient regeneration or improvement.

CONCLUSION

Brachial plexus injuries constitute a public health problem affecting both the patient and his/her family. One of the greatest problems for peripheral nerve surgeons is to reduce functional loss due to brachial plexus injuries. Neurotization is an alternative approach particularly for patients with root avulsions in whom any other technique would not achieve promising functional outcomes. It takes a long time to regain lost function after neurotization in brachial plexus root avulsion injuries. Although neurotization is reported to provide good results for shoulder and elbow functions, functional outcomes following finger and wrist neurotization are far from expected for fine and complex motor skills. Physical therapy and rehabilitation are very important in the postoperative period. It should be always kept in mind that the acquirement of even a small amount of function is important for the patient.

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