

Surgical treatment of peripheral nerve injuries: Better outcomes with intraoperative NAP recordings

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ABSTRACT

BACKGROUND: Peripheral nerve injuries are usually not lethal but may cause serious neurological deficits if not treated properly. The aim of this study is to present our patients who underwent surgical treatment for peripheral nerve trauma in the past 10 years and to discuss their results in light of the literature.

METHODS: The clinical and electrophysiological results of 182 patients who underwent surgical treatment in our department between 2010 and 2019 were retrospectively analyzed. All surgeries were performed using intraoperative nerve action potentials (NAP) recordings. Demographic characteristics, etiologies, surgical timing, and results of surgical treatment were recorded.

RESULTS: A total of 199 surgical interventions were performed in 182 patients with peripheral nerve trauma within 10 years. 162 patients were male, 20 were female and the mean age was 29.34 years for males and 30.2 years for females. The sciatic nerve trauma was the most common in men and peroneal nerve injury women. The most common cause of trauma was gunshot wounds in men and blunt/sharp traumas in women. External and internal neurolysis was the most common surgical technique, followed by epineural anastomosis and sural nerve grafting. 155 of 182 patients showed partial neurological improvement within 3 months after surgery, while 27 had no change in their neurological condition.

CONCLUSION: Men are more frequently exposed to peripheral nerve trauma than women. Severe partial nerve lesions mostly benefit from surgical treatment, and neurolysis has become the most preferred method of surgical treatment. Intraoperative NAP recordings provide better clinical outcomes. Neurological improvement may not always be in correlation with electrophysiological improvement.

Keywords: Injury; outcome; peripheral nerve; surgery.

INTRODUCTION

Peripheral nerve injuries are common traumas that may cause serious neurological deficits today.^[1-3] They often occur as a result of glass and sharp tool injuries. In addition, traffic accidents, blunt and penetrating traumas (such as gunshot wounds) can also cause serious damage to the peripheral nerves.^[4-6]

Neurological examination is the most important method that shows any damage to the peripheral nerves after trauma.^[7,8] If any motor or sensory deficit occurs following the trauma, electrophysiological and radiological diagnostic

methods are used to eliminate any peripheral nerve injury. Electromyography (EMG) is currently the most common method of diagnosis in peripheral nerve injuries.^[1,2,9,10] EMG is a diagnostic method that reveals the denervation that occurs in the muscle innervated by the affected nerve. However, it usually provides satisfactory electrophysiological information about the nerve injury 3 weeks after the trauma.^[2,3] In addition, magnetic resonance imaging (MRI) is helpful to reveal the accompanying hematoma secondary to trauma, or for lesions such as neuroma developing weeks to months after trauma.^[1,4] However, it should not be used in patients with multiple metallic shrapnel wounds secondary to gunshot injuries.

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In peripheral nerve injuries, treatment is conservative or surgical.^[1,11,12] This is determined by the patient's age, the affected nerve, the condition of the nerve, the type of trauma, the neurological, clinical, and electrophysiological status of the patient.^[1,3,5] Physical therapy, analgesic/anti-inflammatory agents, various splints are the methods used in conservative treatment.^[2,4] Neurolysis, neuroraphy, and neurotization techniques can be performed as a surgical treatment method.^[1,4,5,8]

The aim of our study is to present the clinical results of patients hospitalized in our clinic for the past 10 years due to peripheral nerve injury and underwent surgical treatment and to discuss them in light of current literature.

MATERIALS AND METHODS

This retrospective study was approved by University of Health Sciences Non-Interventional Ethics Committee (Approval date: 09.05.2020, Approval No: 2020/159). We declare that the work described has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki). Informed consent was obtained from all patients before surgery.

In this study, the data of patients who underwent surgical treatment for peripheral nerve injury at the Department of Neurosurgery, Gulhane Training and Research Hospital between 2010 and 2019 were retrospectively reviewed. Only trauma patients were included in the study, and tunnel syndromes, peripheral nerve tumors, and other peripheral nerve diseases were excluded from the study. In some pa-

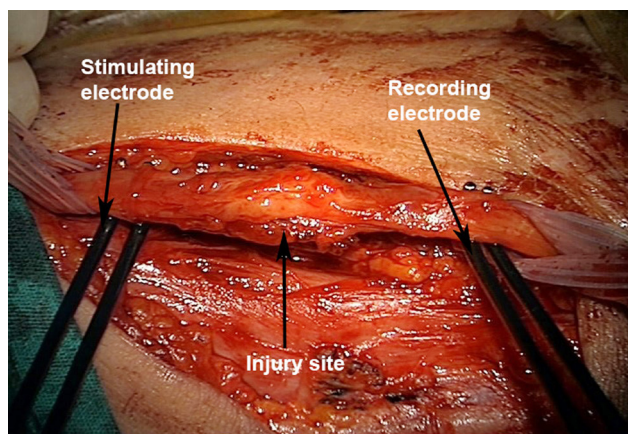


Figure 1. Picture of intraoperative nerve action potentials recording using stimulation and recording electrodes.

tients, more than one peripheral nerve lesion has also been detected. These patients were mostly gunshot injuries and traffic accidents. For electrophysiological assessment, EMG was periodically performed in all patients pre- and post-operatively. MRI was performed in the preoperative period in patients who were thought to develop hematoma or neurotoma after trauma. Total neurological deficit was accepted as the indication of surgery and total axonal or severe partial axonal degeneration was accepted as an indication of surgery electrophysiologically. As a treatment algorithm, the physical therapy process was firstly performed in all patients and patients who did not benefit from the physical therapy and had total or near-total neurological deficits underwent surgical treatment. Intraoperative neuromonitoring was performed using intraoperative nerve action potentials (NAP) recordings in all patients (Fig. 1). The electrical stimulus was generated from the proximal and distal parts of the injured nerve and the responses were recorded from the distal muscles with electrodes. The latency and amplitudes of responses were evaluated intraoperatively to assess the efficacy of surgery. Demographic features, pre- and postoperative neurological examinations, electrophysiological test results, and surgical techniques were investigated in detail.

RESULTS

During the past 10 years, 182 patients in our clinic received surgical treatment due to peripheral nerve trauma. A total of 199 peripheral nerve surgery were performed on these patients. 162 of these patients were male and 20 were female. The mean age is 29.34 years (ranged 7–62 years) in male patients and 30.2 years (ranged 3–67 years) in female patients. A total of 178 peripheral nerve lesions were detected in 162 male patients, and 21 peripheral nerve lesions were detected in 20 female patients. The most common cause of injury was gunshot wounds, followed by blunt/sharp traumas, iatrogenic causes, and injections in male patients. In female patients, the most common cause was blunt/sharp traumas, followed by iatrogenic causes, gunshot wounds, and injections. The most common surgery was performed to sciatic nerve lesions (n=52) in the male group and to peroneal nerve lesions (n=8) in female patients. Among the iatrogenic causes, the most common risk factors were bone fracture surgeries (n=19), arthroscopies, and cardiovascular system surgeries (Table 1).

Of the 178 peripheral nerve lesions in the male group, 93 (52.2%) were occurred in the lower extremity nerves, while

Table 1. The demographic features, technique and outcome of patients with peripheral nerve injury

Sex	Number of patient	Mean age (years)	Most common injured nerve	Most common etiology	Most common surgical technique	Neurological improvement
Man	162	29.34	Sciatic nerve	Gunshot injury	Neurolysis	140
Woman	20	30.20	Peroneal nerve	Blunt/sharp injury	Neurolysis	15

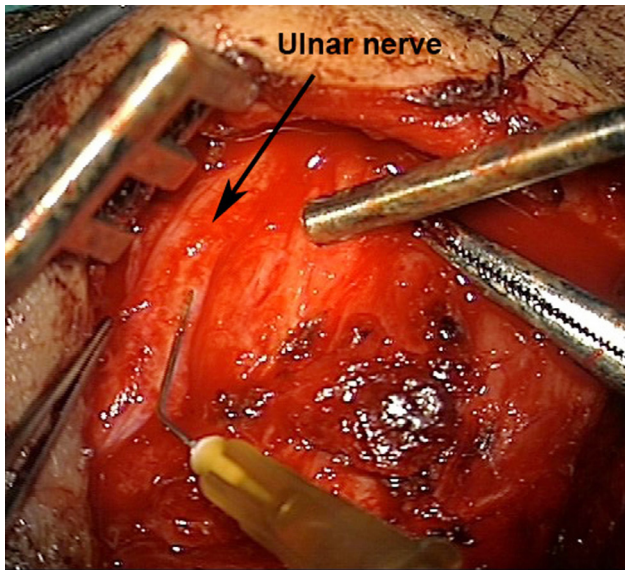


Figure 2. Intraoperative picture shows internal neurolysis after ulnar nerve decompression.

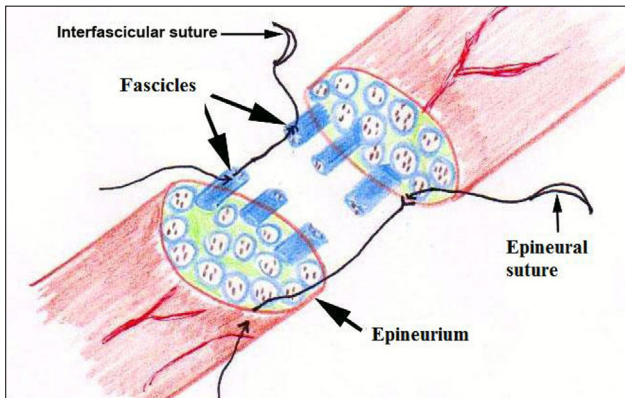


Figure 3. Line drawing depicting epineural and interfascicular anastomosis.

12 (57.1%) of 21 lesions in the lower extremities in the female group. Peripheral nerve injury was more frequent in the lower extremity nerves in both genders.

EMG was performed on all patients, and in the majority of patients, severe partial axonal degeneration and total axonal degeneration were detected in preoperative EMG. In the majority of patients, 5/5 motor deficits were present in the muscles that innervated by the injured nerve.

The mean period between injury and surgical treatment was 3.4 months, and surgery was performed at the earliest 5 days and at the latest 10 months later. Early surgical treatment was performed to 15 (8.2%) patients with hematoma in the trauma region and with sciatic nerve lesions after injection.

Among the 199 nerve lesions, external and internal neurolysis (Fig. 2) (n=173) was performed most frequently as the main surgical treatment technique, followed by epineural anastomosis (Figs. 3 and 4) (n=20) and sural nerve grafting (Fig. 5) (n=6).

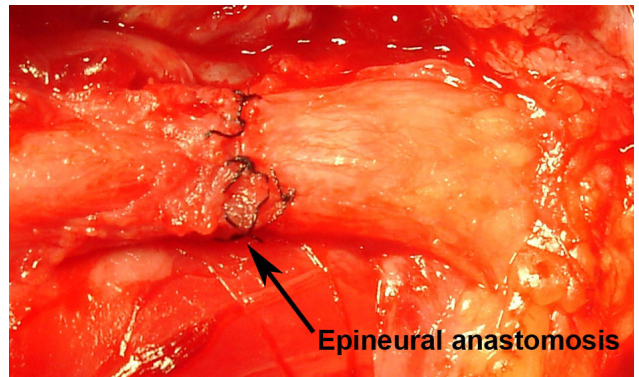


Figure 4. Picture shows epineural anastomosis

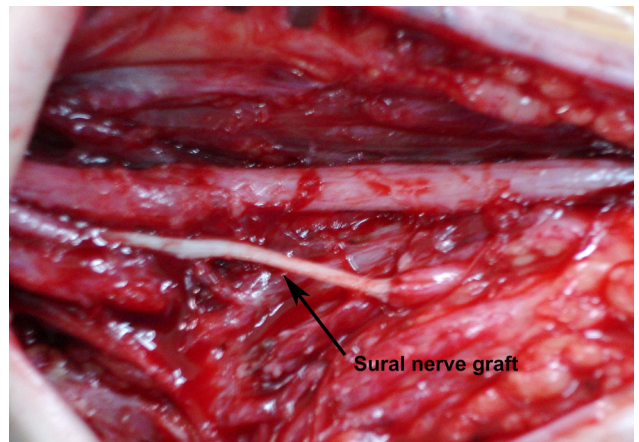


Figure 5. Picture shows peripheral nerve anastomosis using sural nerve grafting.

155 (85.2%) of 182 patients showed partial neurological improvement within 3 months after surgery, while 27 patients did not have any change in their neurological condition. Electrophysiologically, 134 (73.6%) patients were recovered and 48 patients did not show any electrophysiological improvement. Although electrophysiological improvement was not observed in 19 (10.4%) patients, neurological improvement was observed.

DISCUSSION

The peripheral nervous system is a system formed by neural structures originating from the spinal roots of the spinal cord. These nerves contain sensory, motor, and autonomic nerve fibers. The axons of the lower (second) motor neurons, which are located in the anterior horn of the spinal cord, leave the spinal cord from the anterior root and form the peripheral motor nerves. The cell bodies of the peripheral sensory axons are located in the posterior root ganglion located outside the spinal cord within the intervertebral foramen.^[13]

There are three main injury types of the peripheral nerve. These are Wallerian degeneration, axonal degeneration and segmental demyelination. Wallerian degeneration is the damage of peripheral nerve's axon for any reason (such as trauma,

infarction, prolonged or severe pressure) and disturbance of its integrity. In axonal degeneration, there is damage in the peripheral nerve cell body or axon secondary to toxic or metabolic injuries. Segmental demyelination involves damage on the myelin sheath and/or Schwann cells without any damage on the peripheral nerve axon. This condition is mostly seen in demyelinating diseases or hereditary neuropathies.^[14]

All kinds of trauma (such as firearm injury, sharp tool injury, electric shock, burns, crushes) lead to varying degrees of peripheral nerve injury, from the mildest to the most painful.^[14,15,16] While gunshot injuries are at the forefront of military medicine, injuries due to traffic accidents and injuries with a sharp tool (glass or knife) are more common in civilian life.^[4,15,16] Burns and crushes are mostly seen after the earthquake.^[17,18] Electric shocks are rarely seen. Iatrogenic peripheral nerve injuries may also be developed secondary to previous humerus, femur, and joint operations. In our clinic, peripheral nerve injuries were most frequently observed due to gunshot injuries in the male group and secondary to sharp/blunt injuries in women.

Different surgical techniques are used in the treatment of peripheral nerve injuries.^[5,9,19] These are neurolysis, anastomosis (epineural and interfascicular), and neuritization.^[1,4,19] Sometimes, vascular injuries may be associated with nerve lesions, especially in brachial plexus traumas.^[15,19,20] Neurolysis is the most common surgical technique in the world and it has two different types, external and internal. If the integrity of the epineurium is impaired and the nerve is surrounded with fibrotic tissue, internal neurolysis is preferred (Fig. 2). If the integrity of the epineurium is preserved, external neurolysis is performed to decompress the nerve.^[1,3,4] In cases where the nerve is ruptured, anastomosis is the only option and it can be performed epineurally or interfascicularly (Fig. 3). Although there are publications about better clinical results with interfascicular anastomosis, there is no consensus on the preference of anastomosis.^[1,4] External and internal neurolysis technique were most frequently performed in our clinic, followed by epineural anastomosis. The best clinical result was obtained after the neurolysis technique. In addition, radial nerve lesions secondary to iatrogenic causes were mostly benefited from the surgical treatment. Radial nerve injuries are usually seen after humerus fractures. Ljungquist et al.^[21] suggested to perform primary radial nerve repair without applying any tension if the lesion is located in a well-vascularized area. Terzis and Konofaos^[22] published the results of 35 patients who underwent surgical treatment due to radial nerve lesions and emphasized that younger patients and lesions with nerve continuity had better results if surgery was performed no later than 3 months. In our series, we mostly performed the surgeries between 3 and 6 months and obtained satisfactory clinical results.

Ulnar nerve injuries are slightly different from other nerve injuries. The ulnar nerve has a delicate structure and can be easily damaged especially in the cubital traumas. It can be seen

in adults as well as in children.^[11] Damage due to gunshot wounds is rare.^[17,23] Secer et al.^[4] analyzed the results of 407 ulnar nerve lesions secondary to gunshot wounds and reported that the critical period for surgical treatment was 6 months and the optimal graft length for nerve repair was 5 cm.

Median nerve injuries may cause sensory or motor deficits in the upper extremities. Proximal median nerve injury may result in weakness of the flexor pollicis longus, pronator teres, flexor carpi radialis, palmaris longus, and flexor digitorum profundus muscles. Weakness of opposition may be seen in these patients because of the median nerve-innervated thenar muscle paralysis. Tinel's sign may develop over the site of nerve injury in patients with median nerve lesion.^[24] Roganovic reported results of missile-caused median nerve injuries in 81 patients and concluded that the level of repair, duration of preoperative period, and length of nerve defect significantly influence the outcome of median nerve repair.^[16]

The timing of surgical treatment is also important factor for recovery. While some authors recommend early surgery, the generally accepted opinion is to perform surgery between 3 and 6 months.^[1,3,4,16] Gezercan et al.^[10] published the clinical results of 25 patients who underwent late surgery and claimed that these patients could achieve a positive result. In our clinical series, the operation time was 3.4 months after trauma, and surgery was performed at the earliest 5 days and at the latest 10 months later. Early surgery was performed in patients with hematoma in the trauma region and patients who developed a sciatic nerve lesion secondary to injection.

Surgical treatment of plexus injuries is more difficult than a single peripheral nerve injury.^[19,20,25,26] There are 2 plexuses in the human body that are mostly exposed to trauma. These are the brachial and lumbar plexuses. Although the brachial plexus has a complex structure, it is most frequently exposed to trauma then the lumbar plexus.^[26] In addition, surgical treatment of brachial plexus lesions is challenging due to its complex anatomical structure. Secer et al.^[19] published the results of 165 brachial plexus injuries due to gunshot wounds and stated that patients with total motor deficit more benefited from surgical treatment with the selection of appropriate surgical techniques. Although the lumbar plexus has a delicate structure, it is more difficult to be affected by trauma due to its deep location and it is mostly injured after birth traumas.^[27,28] However, it can also be injured after severe traffic accidents and gunshot wounds.

Injections are one of the most common causes of sciatic nerve damage.^[3,7] In particular, analgesic and anti-inflammatory agent injections into the gluteal muscle can cause serious sciatic nerve damage. The nerve can be damaged due to direct trauma of the needle or with the neurotoxic effect of the agent.^[1] Some authors recommend emergency surgery for these injuries. Topuz et al.^[7] examined 73 injection-related sciatic nerve lesions, and if there are findings suggestive of

severe sciatic nerve damage, they recommended emergency surgery without waiting for any electrophysiological confirmation. In our series, a total of 11 patients developed injection-induced sciatic nerve lesions and early surgical intervention was performed in these patients.

Prognostic factors in peripheral nerve injuries are still controversial. It is difficult to determine which patient group will benefit from which treatment method.^[9] Topuz et al.^[5] published the results of 28 cases who underwent surgical treatment for peripheral nerve lesions due to gunshot wounds and suggested the surgical treatment in this type of nerve lesions within the first 6 months. Temiz et al.^[3] reported the results of 46 peripheral nerve lesions that were surgically treated and showed that age was not effective in prognosis, and neuromonitoring positively contributed to surgical outcome. Daneyemez et al. reported the results of 1565 patients with peripheral nerve injuries who underwent surgical treatment and emphasized that the type of injury, the time of injury, and the level of neurological deficit after injury are important in the prognosis of peripheral nerve lesions. Pannell et al.^[18] evaluated the results of 41 peripheral nerve lesions due to gunshot wounds in the lower extremity and reported the existence of many fractures, retained fragments, and vascular damages in these patients. They stated that the frequency of intraoperative nerve damage is higher in patients with neurological deficits. Secer et al.^[1] published the largest series of gunshot injuries in 2008 and emphasized that peripheral nerve type, level of injury, concomitant injuries, electrophysiological findings, time of surgery, intraoperative findings, and surgical technique are important in the prognosis of such lesions.

Intraoperative neuromonitoring using intraoperative NAP recordings is crucial for peripheral nerve surgery. This technique provides real-time electrophysiological data about the condition of the peripheral nerve. It is an easy and safe method for nerve lesions in continuity, and not prolong the duration of surgery. Robert et al.^[29] reported the largest series of peripheral nerve lesions in continuity with intraoperative NAP recording in 1736 patients with 3459 lesions and they concluded that this method is a very useful and informative surgical tool for patients with peripheral nerve lesions. We used intraoperative NAP recordings in all patients with peripheral nerve lesions and obtained satisfactory clinical results after surgery.

Limitations

This study has 2 major limitations. First, the number of cases is low to make a comparison between the previous studies. Second, the study is retrospective and no comparison group is existed for surgical technique.

Conclusion

Gunshot wounds are the most common cause of peripheral nerve lesions in men in our series. Patients with severe partial

nerve lesions and almost complete loss of motor function in neurological examination mostly benefit from the surgical treatment. Combined with decompression, external and internal neurolysis gives the best results when performed under neuromonitoring. It should be kept in mind that neurological improvement may not always be in correlation with electrophysiological improvement.

Ethics Committee Approval: This retrospective study was approved by Health Sciences University Non-Interventional Ethics Committee (Date: 09.05.2020, No: 2020/159).

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Conflict of Interest: None declared.

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ORJİNAL ÇALIŞMA - ÖZET

Periferik sinir yaralanmalarının cerrahi tedavisi: İntrooperatif NAP ile daha iyi sonuçlar

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AMAÇ: Periferik sinir yaralanmaları genellikle öldürücü değildir, ancak uygun şekilde tedavi edilmezse ciddi nörolojik defisitlere neden olabilir. Bu çalışmanın amacı son 10 yılda periferik sinir travması nedeniyle cerrahi tedavi gören hastalarımızı sunmak ve sonuçlarını literatür ışığında tartışmaktır.

GEREÇ VE YÖNTEM: 2010–2019 yılları arasında kliniğimizde cerrahi tedavi uygulanan 182 hastanın klinik ve elektrofizyolojik sonuçları geriye dönük olarak incelendi. Tüm ameliyatlarda intraoperatif sinir aksiyon potansiyelleri kullanıldı. Demografik özellikler, etiyolojiler, cerrahi zamanlama ve cerrahi tedavi sonuçları analiz kaydedildi.

BULGULAR: Periferik sinir travması olan 182 hastaya 10 yıllık bir sürede toplam 199 cerrahi girişim yapıldı. Yüz altmış iki hasta erkek, 20 kadın ve ortalama yaş erkeklerde 29.34 yıl, kadınlarda 30.2 yıl idi. Siyatik sinir travması erkeklerde ve peroneal sinir hasarı kadınlarda en yaygın olanıdır. Travmanın en yaygın nedeni erkeklerde ateşli silah yaralanmaları ve kadınlarda ise künt/kesicitravmalar idi. Eksternal ve internal nöroliz en sık uygulanan cerrahi teknik olup bunu epinöral anastomoz ve sural sinir grefti izlemiştir. Yüz seksen iki hastanın 155'inde ameliyattan sonraki üç ay içinde kısmi nörolojik düzelme görülürken, 27'sinde nörolojik durumlarında değişiklik olmadı.

TARTIŞMA: Erkekler periferik sinir travmasına kadınlardan daha sık maruz kalmaktadır. Şiddetli kısmi sinir lezyonları çoğunlukla cerrahi tedaviden yararlanır ve nöroliz en çok tercih edilen cerrahi tedavi yöntemi haline gelmiştir. İntrooperatif sinir aksiyon potansiyelleri kaydı daha iyi klinik sonuçlar vermektedir. Nörolojik iyileşme her zaman elektrofizyolojik iyileşme ile ilişkili olmayabilir.

Anahtar sözcükler: Cerrahi; periferik sinir; sonuç; yaralanma.

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