ORIGINAL ARTICLE

Radial nerve injuries and outcomes: Our surgical experience

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ABSTRACT

BACKGROUND: The aim of this study was to retrospectively evaluate patients who underwent surgery in our department for radial nerve lesions in terms of surgical outcomes.

METHODS: Thirty-eight patients were admitted to our department with radial nerve lesion. Twenty-seven of the patients had entrapment neuropathy and 11 had radial nerve injury secondary to other traumas. Various factors such as surgical results, time to surgical intervention, injury mechanism, and reconstruction technique were analyzed.

RESULTS: In all of 27 patients who were operated for radial nerve entrapment neuropathy, a complete improvement in wrist dorsal flexion was detected at postoperative 3rd month. Seven of the 11 patients who were operated for radial nerve lesion had different degrees of improvement in wrist dorsal flexion at the postoperative 3rd month. Two of the seven patients underwent anastomosis using a sural nerve graft. The recovery rate in our series was 89%. Three of the 4 patients who did not recover after the radial nerve injury were the patients who were operated within the 1st month after the trauma.

CONCLUSION: Better functional results were obtained in the postoperative period in patients who were operated after the 1st month, underwent internal neurolysis and used a short nerve graft for anastomosis in the radial nerve lesions. In patients with entrapment neuropathy, the earliest surgery revealed satisfactory results in the postoperative period.

Keywords: Entrapment neuropathy; nerve lesion; neurolysis; radial nerve.

INTRODUCTION

Peripheral nerve injuries are important health problems in civilian life, as well as in military practice.[1–4] These injuries may be observed in adults and children.[5] Peripheral nerves are most commonly injured by blunt and penetrating traumas.[3,4] Ulnar, median, radial, and sciatic nerves are the main peripheral nerves that are injured after traumas.[1,2] The radial nerve is the most frequently damaged nerve in the upper extremity and observed more common especially in patients with multiple traumas.[6,7] There are many factors that contribute to radial nerve damage such as humerus fractures (traffic accidents, gunshots, etc.), entrapment neuropathies, neuritis, and malignant nerve tumors.[8–12]

Surgical approaches to entrapment neuropathies of radial nerve and traumatic radial nerve lesions are different.[6,7] Decompression is usually sufficient in entrapment neuropathies. However, if there is a total discontinued lesion after a penetrating trauma, end-to-end epineural anastomosis can be performed. In addition, if the gap is excessive (if an epineural anastomosis cannot be performed), anastomosis is performed using a nerve graft. For this purpose, the sural nerve is mostly used.[1]

Medical Research Council Muscle Strength Grading System is used in the extremity motor examinations in the preoperative and postoperative periods of patients with nerve injury (Table 1).[13] There is a difference between the two condi-

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Table 1. Medical research council muscle strength grading system for the extremity motor examination[13]

Grade	Muscle state
0	No contraction
1	Flicker or trace of contraction
2	Active movement with gravity eliminated
3	Active movement against gravity
4	Active movement against gravity and resistance
5	Normal power

tions in terms of the time of surgical intervention as mentioned above. Surgical intervention is generally required in entrapment neuropathies. If there is a complete loss of wrist dorsal flexion during the patient's admission or if there is 2/5 or less muscle strength, surgical intervention should be performed as soon as possible. If there is minor loss of power, the patient should be followed-up for a while with physical therapy and vitamin-B supplement. If there is no improvement, surgical intervention should be performed. However, in nerve lesions secondary to high-energy injuries (such as a gunshot), extensive tissue loss, and infection may occur. In this situation, general and medical conditions of the patients are usually unstable, and it is the best to wait at least 1 month for a surgical nerve repair. This time period may be extended up to 3 months according to the patient's neurological condition.[1–3]

In the study, we retrospectively analyzed 38 patients who presented with clinical symptoms and findings secondary to radial nerve injury between 2015 and 2019.

MATERIALS AND METHODS

Patients Groups

We retrospectively analyzed the data of 38 patients who were presented with clinical symptoms and signs due to radial nerve injury between 2015 and 2019. Thirty-two (84%) of patients were male and 6 (16%) were female. The youngest patient was 13-year-old and the oldest was 57-year-old. The average age was 26 years. Twenty-seven (71%) of the patients had entrapment neuropathy and 11 (29%) patients had clinical findings secondary to other causes of radial nerve lesion. Based on the electrophysiological studies, the radial nerve was entrapped in the spiral groove in all cases with entrapment neuropathies. Etiological factors of radial nerve lesions are shown in Table 2. Among patients with iatrogenic nerve injuries, humerus shaft fracture was detected in 8 patients and radius fracture in 3 patients.

Clinical Evaluation

Preoperative neurological evaluation and electromyography (EMG) were performed in all patients. In 20 patients (74%)

Table 2. Etiology of radial nerve lesions

Causes of injury	Number of patient	
	n	%
Gunshots	5	13.2
Crush	8	21.1
Iatrogenic	25	65.7
Total	38	100

of patients with entrapment neuropathy, there was complete loss of wrist dorsal flexion movement. In 7 patients, muscle strength was 1–2/5 in supination and hand-finger extension. In 9 patients (81%) with radial nerve secondary to other factors, there was complete loss of wrist dorsal flexion movement during admission. Neurological evaluation was also performed in all patients in the early postoperative period. All patients received vitamin-B supplement after the surgical intervention in postoperative period.

Radial Nerve Anatomy and Surgical Technique

The radial nerve originates from the C5-T1 roots and leaves from posterior cord of the brachial plexus. It directly stimulates the triceps, brachioradialis, extensor carpi radialis longus, and anconeus muscles. It stimulates the extensor carpi radialis brevis and the supinator muscle through its deep branch. The posterior interosseous nerve (PIN), which is the continuation of the deep branch, innervates the extensor digitorum, extensor digiti minimi, extensor carpi ulnaris, abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus, and extensor indicis muscles. Of the superficial sensory branches, the posterior brachial cutaneous branch carries the dorsal sensation of the arm, and the posterior antebrachial cutaneous branch carries the sensation of the forearm dorsal section.[14] It gives the sensory posterior brachial cutaneous branch and motor branches innervating the long and lateral heads of the triceps muscle before or immediately after crossing the axillary region.[15] In traumas affecting the axillary region (e.g., prolonged use of crutches, etc.), weakness in all muscles innervated by the radial nerve and sensory defects in the related areas occur. Then the radial nerve passes the triangular cavity to leave the axillary. The lateral border of the triangular space is the humerus, the medial border is the triceps long head and some of the teres major fibers, and the lower border is the teres major upper fibers.

In radial nerve injuries at the 1/3 proximal part of the humerus, since the motor branches innervating the triceps muscle have previously appeared, the power of the triceps may be normal, but extension is not possible in the wrist and metacarpophalangeal joints.

Between the 1/3 proximal and middle part of the humerus, the radial nerve passes between the long and medial heads of

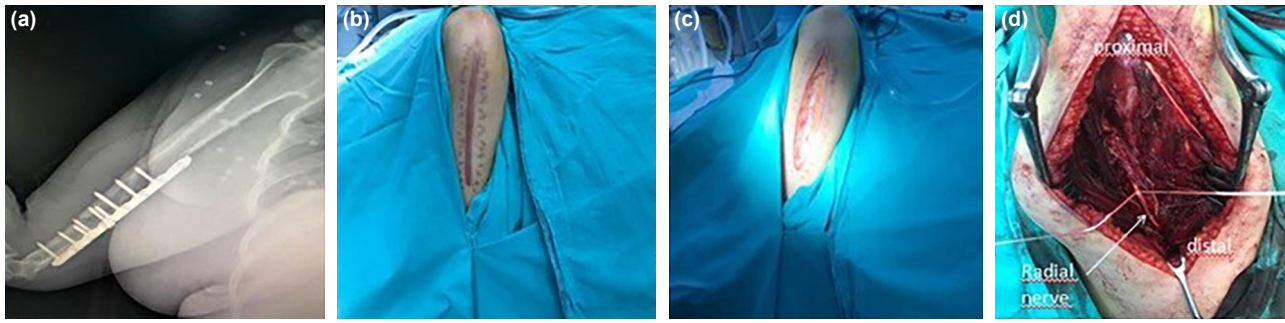

Figure 1. A 35-year-old male patient. Right humerus fracture **(a)** developed after in-car traffic accident. A total loss of right wrist dorsal flexion (grade 0) occurred 15 days after an orthopedic surgery. The incision was made from the previous surgery incision line **(b and c)**. The radial nerve was exposed, and decompression and internal neurolysis were performed **(d)**. At the postoperative 3rd month, the patient's motor deficit resolved completely (grade 5).

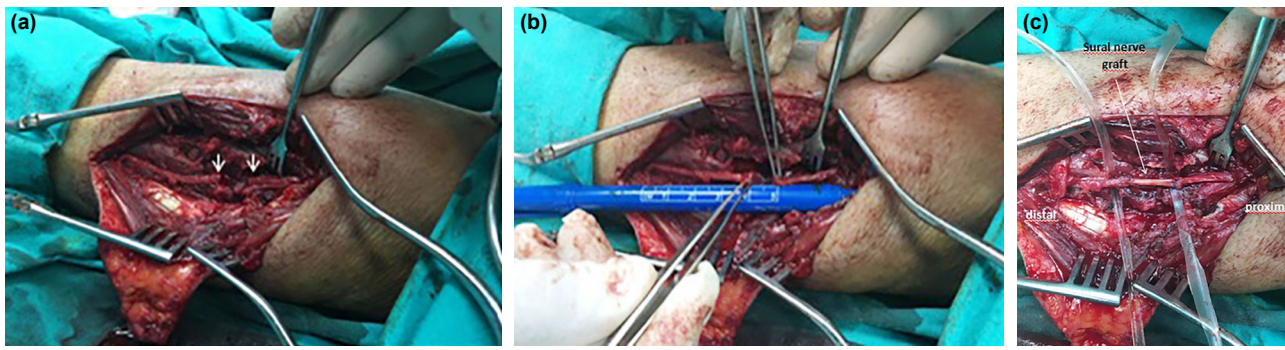

Figure 2. A 23-year-old male patient was admitted to our clinic with a gunshot injury from the left forearm. The muscle strength grade was 5 in the left wrist dorsal flexion. In the 2nd month, surgical intervention was performed using the injury scar tissue. The left radial nerve was exposed and observed as totally ruptured **(a and b)**. Anastomosis was performed using a sural nerve graft **(c)**. It was observed that the patient was able to move his wrist enough to defeat gravity at the postoperative 3rd month (grade 3).

the triceps muscle and proceeds with the deep brachial artery in the humeral spiral groove. Then, it reaches the lateral border of the humerus with the intermuscular septum located in the inferolateral. The spiral groove is the area where the radial nerve is often damaged and most often entrapped. The last branch of the radial nerve in the arm innervates the extensor carpi radialis longus muscle. Damage may occur in cases such as incisive and penetrating traumas, chronic compression (e.g., compression during Saturday night paralysis or anesthesia) or callus formation after an old humeral fracture. In these patients, triceps power is preserved despite the loss of wrist dorsiflexion. The nerve advancing in the lateral intermuscular septum enters the flexor compartment of the arm, piercing the lateral intermuscular septum approximately 8–10 cm above the lateral epicondyle. Here, it travels distal to the arm, between the brachialis in the medial, between the brachioradialis muscles in the lateral and just below the medial border of the brachioradialis muscle and reaches the lateral epicondyle level. This course is also called the "radial tunnel course."[16]

The radial nerve may be exposed to compression and trauma during its superficial course between the extensor carpi radialis longus and brachioradialis muscles in the supinator arch located in the lateral muscular septum, proximal to the forearm called "Frohse arc."[17] The radial nerve passing in front of the lateral epicondyle, at the anterolateral of the antecubital fossa, posterior of the brachioradialis muscle, travels between the brachioradialis and extensor carpi radialis longus muscles. Here, the radial nerve is divided into superficial sensation and deep motor branches (PIN) 3 cm above or below the elbow, giving the motor branch to the extensor carpi radialis brevis muscle.[18] The superficial branch of the isolated sensory nerve, the radial nerve, travels under the brachioradialis muscle and in the anterior of the supinator muscle. In this region, the nerve remains lateral to the radial artery. Approximately 15 cm distal to the elbow area, it becomes superficial between the brachioradialis muscle and the tendons of the extensor carpi radialis longus muscle and protrudes distally. This nerve receives the sensation of the dorsal side of the hand, the dorsal side of the 1st and 2nd fingers, the side up to the proximal interphalangeal joint on the 3rd finger radial side.

Lesions below the plexus level can be best exposed with a posterior or posterolateral approach. In entrapment neuropathies, especially secondary to previous humerus fractures, a linear incision is made in the posterolateral arm to expose the radial nerve (Fig. 1). In nerve injuries due to gunshots and traumatic fractures, an incision involving the injury site is made (Figs. 2 and 3).

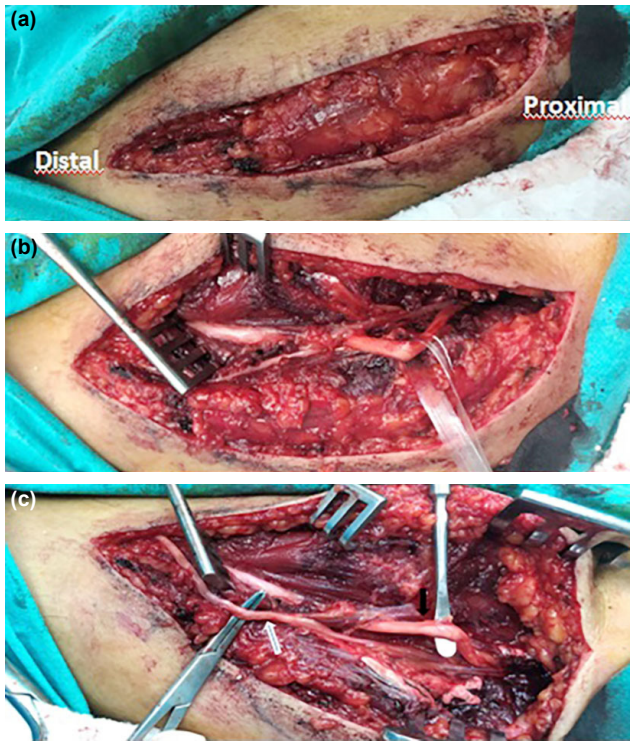

Figure 3. A 48-year-old male patient was admitted with a loss of left wrist dorsal flexion for 3 days. Electromyography was diagnosed an entrapment neuropathy of the radial nerve in the left spiral groove. A linear incision was made lateral to the left arm extending distally **(a)**. Radial nerve was found in the spiral Groove **(b)**. Decompression and internal neurolysis were performed. The black arrow shows the radial nerve, the white arrow identifies the posterior antebrachial cutaneous nerve which is the sensory branch of the radial nerve **(c)**. The patient's power loss began to improve on the postoperative 5th day. At the 1st month control, the degree of muscle strength was grade 5.

All 38 patients with radial nerve lesions were operated. After the diagnosis of entrapment neuropathy with EMG, early surgical treatment was performed in 20 patients with complete loss of wrist dorsal flexion or 2/5 and less muscle strength. In 7 patients, patients with loss of frust strength or 3–4/5 muscle strength were followed up for 3 weeks with medical therapy (vitamin-B complex) and physical therapy. Patients whose neurological condition did not improve after the follow-up period underwent surgery. In these patients, after an incision appropriate for the spiral groove, after passing the skin and subcutaneous, the radial nerve, which courses between the long and medial heads of the triceps muscle, was reached, and the surrounding bands and adhesions were dissected, and the nerve was decompressed and internal neurolysis was performed.

In 11 patients with radial nerve damage due to gunshots or other traumas, 3 patients were operated within the 1st month and 8 patients within 2 and 6 months after the injury. In 5 of these patients, radial nerve was found to be totally ruptured. Three of them underwent end-to-end epineural anastomosis, and 2 patients underwent microsurgical anastomosis using an 8–0 suture and sural nerve graft. In the other 6 patients, the radial nerve was found to be partially ruptured or degenerated, and the bands around it were dissected and decompression was achieved. In all patients with both entrapment neuropathy and nerve lesions, internal neurolysis was performed during surgery. Intraoperative nerve action potential recording was used during surgery in all 11 patients who had radial nerve injury, and no motor response was obtained in 5 patients in the preoperative and peroperative periods.

RESULTS

All patients underwent an early postoperative neurological examination. In 12 of 27 patients operated for the entrapment neuropathy of the radial nerve, an increase in muscle strength was observed in the motor movements at the lowest 1/5 and the highest 3/5 in the early postoperative period. All of the 27 patients came to their controls in the third postoperative mean and all of them were evaluated to have normal neurological examination. Muscle power was detected at the level of 3–4/5 in the postoperative 3rd month follow-up examination in 7 of 11 patients with radial nerve lesions due to traumas. In four patients, no difference was found in neurological status when compared with the preoperative period (Table 3).

DISCUSSION

Radial nerve is originated from the posterior cord of brachial plexus.[17,19] Radial nerve lesion can develop at many levels with different etiologies. It can be entrapped in the proximal segment, spiral groove, or forearm. Posterior interosseous nerve can be compressed and injured in the Frohse arc by repeated pronation and supination movements of the forearm.[6,10]

Table 3. The relationship between denervation time and recovery rates in patients undergoing surgical intervention

Nerve injury		Postoperative recovery (+)		Postoperative recovery (-)	
		Total injury	Partial injury	Total injury	Partial injury
Denervation time	<1 month	0	0	3	0
	>1 month	2	5	0	1
Total		2	5	3	1

Among the causes of radial nerve neuropathy, bone traumas take the first place. In a previous study, 12% of the patients with 237,000 humeral shaft fractures developed radial nerve lesions, and 70% of them recovered spontaneously within 8–16 weeks.[12] In our study, 71% (27 patients) of the patients applied with radial nerve entrapment neuropathy and 29% (11 patients) with radial nerve lesion secondary to other factors such as gunshot wounds. The most common cause of radial nerve lesion was found as humeral shaft fracture in our series. The most common location of entrapment neuropathy in our series was the spiral groove.

Clinical findings may differ depending on the level of damage to the radial nerve. In the spiral groove, motor and sensory fibers are affected by compression at the level of humerus. Weakness occurs in finger and wrist extension. The sensation decreased in the area defined as "snuff pit" on the dorsal side of the thumb, second and third finger of the hand. If there is weakness and decrease reflex on the triceps muscle, the lesion may be at the root or plexus level. If the brachioradialis and extensor carpi radialis longus muscles are affected, the lesion is probably located in the humerus shaft. In proximal radial nerve lesions, complete loss of wrist or finger dorsal flexions and the extension and abduction limitation occurs with thumb.[11,19] In our study, complete loss was detected in the dorsal flexion of the wrist in 29 patients (76%) of patients with radial nerve lesions.

The EMG study provides valuable contributions in determining the severity, localization, acute-chronic distinction, and early surgical planning of the lesion. EMG performed from the 1st week provides differentiation from neuropraxia from axonotmesis and neurotmesis, but it gives the best results around the 3rd week after injury. Therefore, EMG, which is performed in the early post-injury period, should be repeated in the 3rd week after the trauma.

Various factors, such as the patient's age, cause and level of the lesion, associated injuries or lesions (tumors), duration of denervation, gap between nerve endings, type of repair, and surgeon's experience are factors affecting prognosis after surgery.[1,2,20,21]

In our department, patients who diagnosed radial nerve entrapment in the spiral groove by EMG and who had a complete loss of wrist dorsal flexion or muscle strength of 2/5 or less, were operated as soon as possible. Patients admitted with frust motor loss or 3–4/5 muscle strength were followed up with medical and physical therapy. Surgical intervention was preferred in patients whose complaints did not improve. Terzis and Konofaos reported that radial nerve repairs performed in the first 3 months achieved better results in the postoperative period. They stated that the presence of associated nerve injuries due to increased scar tissue and extensive muscle involvement had a negative effect on postoperative recovery.[22] However, in our study, it was evaluated that patients did not benefit from surgery performed in the 1st month.

While taking the sural nerve graft, care was taken to ensure that the graft was not long. The graft was planned to be 1–2 cm long from the existing gap. Indeed, it has been stated in the literature that graft length may affect healing.[21,23] Singh et al. and Haase et al. used short nerve grafts in their study and stated that they obtained better results.[24,25] In patients who underwent anastomosis with sural nerve graft, an improvement in neurological status was detected compared to the preoperative period (muscle strength was 0/5 in both patients during the preoperative period. Muscle strength in the postoperative period was 2/5).

In the postoperative period, control EMG was performed in all cases when they were presented in our outpatient clinic for control. Compared with the preoperative period, EMG changes correlated with changes in neurological status. The rate of improvement after the surgery in our series was 89%. We think that surgical intervention in the entrapment neuropathies early in the application provides better results in the postoperative period. However, we believe that waiting for the first 1–2 months, especially in cases of nerve lesions such as gunshot wounds, will produce better postoperative results. It is thought that internal neurolysis enhances nerve conduction in cases with decompression. In other studies, it has been reported that functional recovery is better in patients undergoing neurolysis of the radial nerve.[22] Neurolysis is a less invasive method and tries to separate intranoral contents from the narrowing scar, while at the same time protecting fascicles with perineural integrity.

Shergill et al. reviewed 260 patients with radial nerve injuries and reported good results in 30% of patients while moderate recovery in 28% of patient and failed in 42% of patients. In addition, severe injury, delayed surgical treatment, and nerve defects larger than 10 cm negatively affected nerve healing.[26] Kim et al. reported a series of 260 radial nerve injuries in 2001. Among 180 patients who underwent surgery, positive results were observed in 91% of patients with primary suture repair, 80% of patients with graft repair and 98% of patients undergoing neurolysis.[27] In our study, better results were obtained in the postoperative period in patients undergoing internal neurolysis and anastomosis using a short graft.

Conclusion

Functional results following surgical intervention in radial nerve lesions and entrapment neuropathies are promising. The time of denervation, the degree of nerve damage, nerve graft length, and surgical technique are important factors contributing to postoperative recovery. To ensure the better recovery in the postoperative period, it is important to make a systematic evaluation of patients. It is vital to perform surgical intervention as soon as possible in entrapment neu-

ropathies and in the optimum conditions in the radial nerve lesions after the first 2 months.

Ethics Committee Approval: This retrospective study was approved by Health Sciences University Non-Interventional Ethics Committee (Date: 15.05.2020, No: 2019/72).

Peer-review: Internally peer-reviewed.

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Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Radial sinir yaralanmaları ve sonuçları: Cerrahi deneyimimiz

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AMAÇ: Bu çalışmanın amacı, merkezimizde radial sinir lezyonu nedeniyle cerrahi müdahale yapılan hastaları cerrahi sonuçları açısından geriye dönük olarak değerlendirmektir.

GEREÇ VE YÖNTEM: Merkezimize radial sinire ait disfonksiyon bulguları ile 38 hasta başvurmuştu. Hastaların 27'sinde radial sinirin tuzak nöropatisi, 11'inde ise farklı nedenlere bağlı radial sinir yaralanması mevcuttu. Cerrahi sonuçlar, cerrahi müdahaleye kadar geçen süre, yaralanma mekanizması, rekonstrüksiyon şekli gibi çeşitli faktörler çalışmamızda analiz edildi.

BULGULAR: Radial sinir tuzak nöropatisi nedeniyle ameliyat edilen 27 hastanın tamamında ameliyat sonrası üçüncü ayda el bileği dorsal fleksionda tamamen düzelme saptandı. Radial sinir hasarı nedeniyle ameliyat edilen 11 hastanın yedisinde ameliyat sonrası üçüncü ayda el bileği dorsal fleksionda değişik derecelerde düzelme saptandı. Yedi hastanın ikisinde sural sinir grefti kullanılarak anastomoz yapılmıştır. Tüm olgularımızda iyileşme oranı %89 olarak değerlendirildi (34 hasta). Radial sinir yaralanması sonrası ameliyat edilen hastalardan iyileşmeyen dört hastanın üçü yaralanma sonrası ilk bir ay içerisinde ameliyat edilen hastalardı.

TARTIŞMA: Radial sinir lezyonlarında ilk bir ay sonrasında ameliyat edilen, internal nörolizis yapılan ve anastomoz için kısa sinir grefti kullanılan hastalarda ameliyat sonrası dönemde daha iyi fonksiyonel sonuçlar elde edildi. Tuzak nöropati ile başvuran hastalarda ise en erken zamanda yapılan cerrahi ameliyat sonrası dönemde yüz güldürücü sonuçlar ortaya çıkarmıştır.

Anahtar sözcükler: Nörolizis; radial sinir; sinir lezyonu; tuzak nöropati.

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