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Primary and Delayed Repair and Nerve Grafting for Treatment of Cut Median and Ulnar Nerves

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Abstract: Traumatic cutting of peripheral nerves of median and ulnar in forearm and wrist can cause disablating sensory and motor disorders in patients' hands. We conducted the present study to compare the results of three surgical methods for repair of injured median and ulnar nerves. We studied 85 patients aged 12-59 years (average, 34±18 years) with 105 cut median and ulnar nerves at forearm and wrist presenting to Tabriz Shohada hospital from 1994 to 2003. The patients followed for 2-10 years. Sixty patients (65 nerves) underwent primary repair, 16 (25 nerves) treated with delayed method and 9 (15 nerves) received nerve graft. Success was obtained in all patients underwent primary repair. The excellent results were common in younger patients. Of 65 nerves (60 patients) repaired by primary method, 25 had excellent result. Of 16 patients 25 nerves (16 patients) underwent delayed repair, 7 was unsuccessful. Of 15 nerves (9 patients) underwent delayed repair, 5 was unsuccessful. It is concluded that the recovery following primary repair was faster than other methods. For reaching excellent results in repairing peripheral nerves, it is important to considering all rules needed for repairing cut peripheral nerves, as well as accurate evaluation and correct repair of injured surrounding soft tissue such as tendons and their synovium and injured vessels.

Key words: Peripheral nerve injury, surgical repair, grafting, primary repair, trauma, surgical method

INTRODUCTION

Peripheral nerve injures are common involving often the upper extremities. These injuries may cause significant deficits impaired functional recovery (Rigoard and Lapierre, 2009; Aberg *et al*., 2008). Median and ulnar nerve injuries are examples of such lesions, occurring as isolated or combined injury of both nerves (Karabeg *et al*., 2009). In contrast to the Central Nervous System (CNS), peripheral nerves have the ability of regenerating. This ability has been utilized for a long time in the treatment of injuries of peripheral nerves (Matejcik and Penzesova, 2006).

The traditional treatment for peripheral nerve injuries is repair by using microsurgical techniques, either by primary nerve suture, secondary (delayed) repair or nerve graft, but research to find more successful methods that could improve recovery is ongoing (Aberg *et al*., 2008; Hasegawa *et al*., 2004; Huang *et al*., 2009; Hattori and Doi, 2006; Hattori *et al*., 2005; Moore *et al*., 2009; Ichihara *et al*., 2009). Their treatment sometimes leads to functional recovery but is mostly incomplete or unpredictable, despite the regular use of sophisticated repair techniques (Rigoard and Lapierre, 2009; Sinis *et al*., 2009). The clinician must clearly understand the peripheral nervous system's responses to injury, which reveal surprising degenerating and spontaneous regenerating abilities (Rigoard and Lapierre, 2009).

The surgical treatment of peripheral nerve injuries is still a challenging and highly demanding procedure. The results have been improved upon by different advances in microsurgical techniques. Nevertheless, the results are not always satisfying, making secondary procedures necessary. Thus, these secondary procedures such as tendon transfers and arthrodesis of different joints must be taken into account during reconstructive planning (Sinis *et al*., 2009).

This study reviews the results of current surgical repair techniques for inducing neurological recovery following traumatic median and ulnar nerve injuries.

MATERIALS AND METHODS

This prospective and descriptive study was performed on patients with cut median or ulnar nerve, presenting to Tabriz Shohada Orthopedic Educational and Treatment center from 1994 to 2003.

A total of 85 patients with 105 cut median and ulnar nerve were studied. Primary repair was performed on 60 patients (65 nerves) including 37 median and 28 ulnar

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Table 1: Method of grading results

Grade	Motor	Sensory	Equivalent on seddon's grading
Excellent	Power MRC 5	Function indistinguishable from normal hand	Good M5 S4
	No wasting or deformity	Good stereognosis, no hypersensitivity	
	No trophic changes	2PD* equivalent to uninjured digits	
Good	Power MRC 4 to 5	Accurate speedy localization	Good M5 S3+
	Abolition of paralytic deformity	Can recognize textures or objects	
	Minimal pulp wasting	Minor cold sensitivity and hypersensitivity	
		2PD≤8mm at tips of fingers	
Fair	MRC 3 or more	Accurate localization to digit	Fair M3 S3
	Some sweating	No streognosis, 2PD>8 mm	
	Pump wasted	Significant cold sensitivity and hypersensitivity	
Bad	MRC 3 or less	No sensation or	Bad M O1 or 2 S
	No sweating	Severe cold sensitivity and hypersensitivity	O1 or 2
	Trophic changes		

*Two-point discrimination

Table 2: Grading of muscular force

Grade	Rating	Muscle strength	Assessment
0	Zero	No palpable contraction	Nothing
1	Trace	Muscle contracts, but no movement of the bone	Trace
2	Poor	Muscle moves the bone, but not against gravity	With gravity eliminated
3	Fair	Muscle moves the bone through a full range of motion against gravity	Against gravity
4	Good	Muscle moves the bone against resistance	Near normal
5	Excellent	Normal strength against full resistance	Normal

nerves. Secondary (delayed) repair was performed on patients (25 nerves) including 14 median and 11 ulnar nerves. Nerve grafting was performed on 9 patients (15 nerves) including 9 median and 6 ulnar nerves.

Surgery technique: The nerve repair was conducted as end to end (epi-epineurium, epi-perineurium) anastomosis using operation room microscope or occasionally by loop. This was performed following the tendons and muscles repair (if present) and removing tourniquet. Occasionally, delayed repair required nerve release or even redirecting it. This was performed in three cases of ulnar nerve damage. In some cases we performed limb positioning for lowering tension on nerve repair site. In all cases of nerve grafts we used sural nerve for grafting. The repair in these cases was performed as interfacicular using microscope or loop.

Postoperative cares were including limb immobilization by cast splint for 4-6 weeks (2-3 weeks in cases without grafting), with paying attention to active finger motions and avoiding from fixed deformities.

The results of surgeries on peripheral nerves were evaluated as Excellent, Good, Fair, or Bad according to the Seddon classification (Table 1) (Matejcik and Penzesova, 2006; Ertem *et al*., 2005).

The injured hands were examinated for fixed deformity, muscular atrophy, trophic changes and sweating. The muscular force was evaluated using MRC table (Table 2) (Shergill *et al*., 2001). Immanent palsy deformities were recorded. The sensory examination was including pin prick, light touch, two-point discrimination and diagnosis of things' shape and volume.

RESULTS

We studied 85 patients with 105 median and ulnar nerve cut. The basic information of studied patients is shown in Table 3.

Of all 105 nerves, 65 underwent primary repair. The result of primary repair was excellent in 15 cases (23%), good in 36 cases (55%) and fair in 14 cases (22%) ($p<0.05$, significant). The result of secondary (delayed) repair was good in 8 cases (32%), fair in 11 cases (44%) and bad in 6 cases (24%) ($p>0.05$, non-significant). The result of nerve grafting was good in 5 cases (33.3%), fair in 6 cases (40%) and bad in 4 cases (26.6%) ($p>0.05$, non-significant) (Table 4).

The recovery following primary repair was faster than other methods ($p<0.05$, significant). The patients' opinion about their treatment was also recorded including their obligation to change dominant hand or their job, having any problem in daily works, hypersensitivity, cold sensitivity, the level of their problems and the need for narcotic drugs.

The results showed that the paresthesia of fifth finger was present and oppressive after repair of ulnar nerve, even in presence of good recovery of inter-osseous muscles.

The excellent results as complete recovery was achieved in low group of patients. In good results the muscles force was 5 (according MRC table). We had any palsy deformity. The results of two point discrimination were good. The patients diagnosed the subjects' shape and volume. In fair results, the muscles efficacy recovered but there were immanent palsy deformities. Inter-osseous

Table 3: The basic information of studied patients

Type of repair	Primary	Delayed	Grafting	p-value
No. of patients (nerves)	60 (65)	16 (25)	9 (15)	<0.05
Age (year)	12-59	20-45	16-40	>0.05
Nerve				
Median	37	14	9	>0.05
Ulnar	28	11	6	>0.05
Delay for repair (w)	-	4-12	3-23	>0.05
The distance between two cut end (cm)	-	1.5-3	3-6	>0.05
Repair to examination time (w)	96-432	96-480	96-480	>0.05

Table 4: The results of repair in 85 patients with 105 cut median and ulnar nerve

Result s	Nerve	Primary repair	Delayed repair	Nerve grafting	p-value
Excellent	Median	6	-	-	<0.05
	Ulnar	9	-	-	
Good	Median	17	5	3	<0.05
	Ulnar	19	3	2	
Fair	Median	9	7	3	>0.05
	Ulnar	5	4	3	
Bad	Median	-	4	3	>0.05
	Ulnar	-	2	1	

muscles had not normal efficacy. The fingers had protective sense. In bad results, most of cases did not recover. Some cases had hypersensitivity and cold sensitivity (according patients opinions).

Overall, 10 repaired peripheral nerves were failed, of which 6 have been repaired by delayed method and 4 by nerve graft. The four median nerve repaired by delayed method (3 cases) or nerve graft (one case), were re-explored because of having no recovery. However, there was not any evidence of suture opening on repaired nerves. The neurolysis operation was made on all four nerves, which result in decrease of hypersensitivity and local tenderness in three cases.

The EMG and NCV were performed in 42 patients with fair and bad results.

DISCUSSION

Peripheral nerve injuries are still underestimated (Guerra *et al*., 2007). Peripheral nerve injuries are frequent and generate significant deficits (Rigoard and Lapierre, 2009). Median and ulnar nerve injuries are common, whether isolated or combined injury of both nerve. A nerve graft, if performed in a tensionless manner, has been shown to generally have better results than an end-to-end approximation performed under tension (Karabeg *et al*., 2009).

In our series, the recovery following primary repair was faster than secondary repair. The progress of Tinel's sign to beyond of suture line after 6 month was seen in primary repairs. We need more time for achieving maximum recovery. In some cases (6 patients) which ended to bad results, we found firm adhesions between nerve and surrounding tendons (4 cases) during exploration. In one case the median nerve was entrapped under carpal ligament distal to repair site.

The first publications on the nerve transfer surgery date back to the early 1900s. The potential donor nerves are including intercostal nerves, spinal accessory nerve, phrenic nerve, ipsilateral medial pectoral nerve, partial ulnar nerve, partial median nerve, thoracodorsal nerve, radial nerve to the triceps and C7 nerve roots (Wood and Murray, 2007). Strategies for selecting donor nerve include avoidance of interposed nerve grafting, isolated motor recipient nerve, early transfer and similar diameter between donor nerve and recipient nerves (Wood and Murray, 2007). Regarding all of these factors we used sural nerve for nerve grafting. Satisfactory results after repair of isolated axillary nerve lesions using sural nerve autografts have been reported by Moor *et al*. (2009). Sensory nerves are most often selected for autografting because of their relative ease of procurement and low donor site morbidity (Neubauer *et al*., 2009).

Several factors determine the outcome of repair of peripheral nerves including median and ulnar nerves. The most important influence on the prognosis is the violence of the injury. The length of the graft, arterial injury and an open untidy wound are reflections of this. Delay is a significant factor (Shergill *et al*., 2001). Karabeg *et al*. (2009) had 31 patients with median nerve grafting. They achieved sensory recovery S4 in 3 (10%) patients, S3+ in 9 (29%) patients, S3 in 8 (25.5%) patients, 52 in 9 (29%) patients and S2 in 2 (6.5%) patients. They had 24 patients with ulnar nerve grafting. They achieved S4 sensory recovery in 2 (8.5%) patients, S3+ in 6 (25%) patients, 53 in 5 (21%) patients, S2 in 10 (41%) patients and S2 in 1 (4%) patient. There was no significant difference in sensory recovery of median and ulnar nerve. There was not statistically significant difference by age and level of injury (Karabeg *et al*., 2009). Other studies showed that the results of reconstruction operations of peripheral nerves injuries were dependent on the patient's age, the period between the injury and operation, the length of the autograft, the location of the injury, the type of injured nerve and the character of the injury (Matejcik and Penzesova, 2006). The outcome of ulnar nerve repair depends significantly on the repair level, preoperative interval, associated median nerve injury, length of the nerve defect and age of the patient. High-level ulnar nerve repair is probably useless if performed in the classic manner (Roganovic, 2004).

Roganovic studied outcomes of 128 repairs of missile-caused ulnar nerve injuries. Worsening of the outcome was related to nerve defect longer than 4.5 cm, preoperative interval longer than 5.5 months and age older than 23 years (Roganovic, 2004). In Ertem *et al.* (2005) study, in the age group of 0-15 years, the results were very good in all the patients (100%), but good and very good results accounted for only 20% in the age group of 46 years or above. So, in clean-cut nerve injuries, primary repair must be the first choice. Taking the low regeneration capacity into consideration, priority should be given to reconstructive procedures in patients at older ages (Ertem *et al*., 2005).

Early surgical repair of a nerve lesion predict a better outcome. A good functional motor recovery is dependent on the age of the patient. In Guerra *et al.* (2007) study, all patients ≤20 years demonstrated good or excellent sensori-motor recovery. A good functional outcome was observed in 79% of the patients older than 20 years (Guerra *et al*., 2007). Ertem *et al.* (2005) studied 42 patients treated for forearm clean-cut injuries. There were 51 nerve injuries affecting the median (n = 30) and ulnar (n = 21) nerves. The clinical and functional results of primary repairs were less favorable than those of secondary repairs, although the difference was not significant. The injury level, associated injuries and age did not influence the Seddon scores significantly.

The graft length and denervation time significantly influenced the functional outcome in sensory recovery. The results are significantly better in patients with short grafts than in long ones and in patients who have undergone surgical repair within 6 months (Karabeg *et al*., 2009). Mechanism of injury impacted on the results. Two point discrimination (2PD) testing using a paperclip is a cheap, easily and quickly performed reproducible test of tactile gnosis and should be included in nerve assessment protocols (Karabeg *et al*., 2009). We studied 2PD and other neurologic tests for evaluation of patients' neurologic status.

Type of the peripheral nerve, injury (repair) level, associated injuries, electrophysiologic findings, operation time, intraoperative findings, surgical techniques and postoperative physical rehabilitation are the prognostic factors for peripheral nerve lesions (Secer *et al*., 2008; Roganovic and Pavlicevic, 2006). The level of repair, duration of preoperative interval and length of nerve defect significantly influence outcome after median nerve repair, but only level of repair and duration of preoperative interval are reported as independent predictors for successful outcome (Roganovic, 2005). Secer *et al.* (2008) studied 2210 peripheral nerve lesions in 2106 patients who sustained gunshot injury. In their study, the median nerve lesions showed the best recovery rate, whereas the ulnar nerve lesions had the worst. However, we did not obtain any significant difference between the recovery rate of median and ulnar nerves. Sensory recovery after an isolated ulnar nerve lesion at the wrist is better than after an isolated median nerve lesion but there is no difference in the motor recovery. Combined median and ulnar lesions have an especially bad prognosis and may require secondary palliative surgery. The existence of nerve contusion and a high number of tendon injuries were factors associated with a poorer prognosis (Kilinc *et al*., 2009). Sensory recovery potential is similar for the median and ulnar nerves but motor recovery potential differed significantly. After high-level repairs, motor recovery was better for the radial nerves, than for the ulnar nerves. After intermediate-level repairs, motor recovery was better for the radial, than for the median and ulnar nerves. After low-level repairs, motor recovery potential was similar for all nerves (Roganovic and Pavlicevic, 2006).

Roganovic studied outcomes of 81 repairs of missile-caused median nerve injuries. Average nerve defect and preoperative interval were both significantly shorter for patients with successful outcome than for those with unsuccessful outcome (Roganovic, 2005). Renner *et al.* (2004) performed nerve transplantations in 281 patients. Reconstructions were applied on the median nerve in 59 patients, ulnar nerve in 48, median and ulnar nerves in 23, radial nerve in ten and digital nerves in 141 patients. In patients with median nerve transplantation M3 or better results were seen in 69%, with M3 being 45.2%. S3 or better was observed in 64.3%, with S3 being 47.6%. In patients after ulnar nerve transplantation M3 or better result was achieved in 56.8%, M3 being 19%. S3 or better result was seen in 32.4%, S3 being 27%. In patients who underwent median and ulnar nerve transplantations M3 or better result was seen in 36.8%, M3 being 26.3%. S3 was in 42.1%, while S4 did not occur. In patients after radial nerve transplantation M3 or better effect resulted in 87.5%, M3 being 12.5%.

The best result can be achieved with nerve suturing, performed as an optimum from all aspects. However, as far as the surgical technique is concerned, results of using interfascicular grafts are more advantageous than epineural nerve suture based on compromises. If a nerve graft is longer than 2cm, late results will gradually deteriorating. However, the final outcome definitely depends on the patient's age and the time elapsed from the injury to the operation (Renner *et al*., 2004). For gaps <2 cm neurological recovery is moderate, for gaps 2-4 cm

recovery is generally poor and for gaps >4 cm recovery is limited to non-existent. The limited recovery is because sensory nerves act as passive scaffolds for axon regeneration and do not actively promote axon regeneration. However, such grafts remain the gold standard for nerve repairs. New techniques are required that induce improved neurological recovery (Reyes *et al*., 2005).

If a peripheral nerve is crushed, or if the nerve is cut and the ends sutured together soon after the lesion (anastomosed), neurological recovery is good. When a length of a peripheral nerve is destroyed and anastomosis is not possible, the standard surgical repair technique is to graft a length/s of sensory nerve from the patient, into the gap (Reyes *et al*., 2005).

Kürklü *et al*. (2005) in a study on rabbits demonstrated that treatment of neural defects by the distraction method (primary repair) results in much better results than the grafting method. Barrios *et al*. (1990) studied 44 patients with complete section of the ulnar nerve. Useful ulnar motor function was restored in 22/33 cases of fascicular grafting, in 4/4 of fascicular suture and in 3/7 of epineural suture. Sensibility recovered in 23/33 patients operated on by fascicular grafts and in 10 of 11 treated by epineural or fascicular suture.

In Barrios *et al*. (1990) study, cases with unsatisfactory results had other associated severe lesions, such as median nerve section, vascular damage or tendon injuries. Early repair of clean-cut nerve sections by fascicular or epineural suture gives a good chance for recovery. Grafting should be performed within 3 months and no later than 1 year after the injury. Guerra *et al*. (2007) examined the outcomes of surgical treatment of the upper extremities nerve lesions. Surgical management included primary nerve suture in 16, neurolysis in 25 and nerve grafting in 59 patients. The length of grafts, in cases of secondary nerve reconstruction, did not influence functional outcome. Traumatic nerve lesions, without signs of reinnervation, should be treated surgically within a period of three months after injury.

CONCLUSIONS

The recovery following primary repair was faster than other methods. For reaching excellent results in repairing peripheral nerves, it is important to considering all rules needed for repairing cut peripheral nerves, as well as accurate evaluation and correct repair of injured surrounding soft tissue such as tendons and their synovium and injured vessels. Also, accurate conducting of postoperative cares and on time physiotherapy and patient good cooperation may affect treatment results.

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