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Prognostic Factors for the Surgical Management of Peripheral Nerve Lesions

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Daneyemez, M., Solmaz, I. and Izci, Y. *Prognostic Factors for the Surgical Management of Peripheral Nerve Lesions*. Tohoku J. Exp. Med., 2005, **205** (3), 269-275 ── Although the evaluation and treatment of patients with peripheral nerve injuries has evolved and improved over the years, there are still some arguments on the methods and results of surgery. We reviewed retrospectively the clinical, electrophysiological and surgical characteristics of peripheral nerve lesions for 1,636 nerves in 1,565 patients who had been managed in our department in a 10-year period. The most common cause of injuries was gunshot wound in 56.3% of all patients, followed by sharp lacerations (20.6%), fractures (10.6%) and tractions (5.1%). Among 1,636 cases of nerve injuries, the most frequently wounded nerve was median nerve (32.3%), followed by ulnar (24.1%), radial (12.1%), sciatic (10.7%) and peroneal nerves (7.7%), and brachial plexus (7.7%). Simple decompression was the most preferred technique for nerve repair in 27.8%. The electrophysiological improvement was observed in 66.8%, as assessed by electromyography. Clinical improvement was found in 58.4%, as judged by muscle strength grading. If the nerve is compressed or contused, but remains intact, the improvement is satisfactory after surgery. The type of injury, its time of occurrence, initial deficit, and degree of recovery expected are important issues in establishing the treatment plan, which may range from skilled observation to extensive surgical intervention. ──── peripheral nerve; injury; surgery; electrophysiology
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Advances in instrumentation and microsurgical technique have improved our management of major peripheral nerve injuries. However, the mechanism and extent of injury remain the chief influences on the degree of motor and sensory recovery (Gentili et al. 1996). Before World War II, a variety of ambiguous terms were used to describe nerve injuries. In 1943, Seddon introduced a classification of nerve injuries based on three fundamental types of fiber nerve injury. While he admitted that his classification, in its simplicity, was only arough approximation, his three original terms, neurapraxia, axonotmesis, and neurotmesis, have become widely accepted (Seddon 1943). Subsequently, Sunderland proposed a classification based on five degrees of injury of increasing severity (Sunderland 1978). Both systems attempt to correlate the degree of damage with clinical symptomatology. However, neural injury is a continuum, and clear distinction between one grade and another is often not possible.

We analyzed the clinical, electrophysiologi-

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cal and surgical characteristics of 1,565 patients with 1,636 peripheral nerve injuries and reported the results of surgical management.

Patients and Methods

Instutional approval of this study was given from the ethical committee of Gulhane Military Medical Academy. We reviewed 1,636 peripheral nerve injuries in 1,565 patients who underwent surgical treatment between 1992 and 2002 at the Department of Neurosurgery, Gulhane Military Medical Academy. The mean age at the time of injury was 24.7 years, ranging between 5 and 58 years. The cause of each peripheral nerve injury was recorded precisely at the time of admission. All patients underwent neurological and electrophysiological evaluations in either preoperative and postoperative periods. The muscle strength grading system was used for the clinical evaluation (Table 1) and electromyography (EMG) was performed for electrophysiological assessment. The EMG findings were classified into two groups: partial axonal degeneration (PAD) and total axonal degeneration (TAD). The prolongation of distal latency in EMG was interpreted as PAD and the absence of distal latency in EMG was interpreted as TAD. Only EMG was employed for electrophysiological assessment of the patients either preoperatively and postoperatively.

All patients underwent surgical treatment. Preoperative preparation of the skin was ensured to allow for the extension of the incision both proximally and distally. The skin incision was planned so that the neuroraphy would not lie directly beneath the incision line and the incision was curved on joint surfaces. Wide exposure was used for the operative approach of nerve repair. Surgical exploration was done through normal anatomical planes above and below the area of injury. After the identification of the nerve proximal and distal to the lesion, dissection with operating microscope was furthered in the area of injury. The different types of surgery were used according to the intraoperative findings, including simple decompression, end-to-end epineurial anastomosis, partial neuroma excision, end-to-end interfascicular anastomosis, and interfascicular anastomosis using sural nerve graft. Internal and external neurolysis were performed classically for each patient. All anastomosis were performed under operating microscope and with micro-instruments. 6 / 0 silk suture was used for epineurial anastomosis and 10 / 0 monofilament silk suture was used for interfascicular anastomosis. In graft required lesions, the involved nerve ends were trimmed until healthy axon bundles could be seen. The length and the thickness of sural nerve grafts were determined depending on the involved nerve diameter and nerve gap.

Postoperative clinical and electrophysiological assessments were performed for all patients with the same criteria of preoperative period. The follow-up period were ranged between 9 to 36 months. The ratio of postoperative normal EMG/preoperative abnormal EMG for each nerve is considered as electrophysiological improvement.

Table 1. *Muscle strength grading system*

Grade	Strength
0	No contraction
1	Flicker or trace contraction
2	Active movement with gravity eliminated
3	Active movement against gravity
4	Active movement against resistance
5	Normal strength

Results

Among 1,565 patients, 1,636 peripheral nerve lesions were detected. The cause of injuries was gunshot wound in 56.3% of lesions followed by sharp laceration in 20.5% and fracture in 10.5% of the lesions (Table 2).

The preoperative EMG and muscle strength grading of all cases were summarized in Table 3. 58% of lesions had total axonal degeneration (TAD) in preoperative evaluation while 42.4% had grade 0 muscle strength. TAD was found in all cases of subscapular nerve lesions, followed by peroneal nerve lesions with 84.2% and sciatic nerve lesions with 84%. The muscle strength grade was 0 in 55.1% of the cases of peroneal nerve lesion.

Simple decompression was the most preferred technique and performed in 27.8% of all peripheral nerve lesions (Table 4). End-to-end interfascicular anastomosis was preferred in 20.3% of cases and end-to-end epineurial anastomosis was performed in 19.9%.

The postoperative electrophysiological and clinical assessments were shown in Table 5. TAD was found in 33.1% of all lesions and EMG was normalized in 28.1% of lesions. The ratio of

TABLE 2. *The summary 1,636 peripheral nerve lesions according to the causes*

Nerve	Gunshot wound	Sharp laceration	Fracture	Traction	Iatrogenic	Others	Total
Median	297	113	44	28	22	25	529
Ulnar	192	110	57	16	18	2	395
Radial	121	39	23	5	10	0	198
Axillary	7	1	1	0	0	2	11
Musculocutaneous	5	1	0	0	1	1	8
Subscapular	1	1	0	0	0	0	2
Brachial plexus	74	17	12	21	2	0	126
Lumbosacral plexus	5	0	0	0	0	0	5
Sciatic	95	32	25	7	17	0	176
Peroneal	84	13	9	6	12	3	127
Tibial	32	4	2	0	1	2	41
Femoral	8	6	0	0	4	0	18
Total	921	337	173	83	87	35	1,636

TABLE 3. *The preoperative electromyography and muscle strength grading*

Nerve	EMG		Muscle strength grading						Total
	PAD	TAD	0	1	2	3	4	5	
Median	258	271	210	81	75	68	57	38	529
Ulnar	176	219	155	94	53	38	41	14	395
Radial	118	80	95	56	27	9	7	4	198
Axillary	3	8	5	3	1	1	1	0	11
Musculocutaneous	3	5	4	1	1	2	0	0	8
Subscapular	0	2	1	1	0	0	0	0	2
Brachial plexus	49	77	52	39	10	10	11	4	126
Lumbosacral plexus	5	0	0	0	2	2	1	0	5
Sciatic	28	148	87	42	23	11	10	3	176
Peroneal	20	107	70	27	9	13	6	2	127
Tibial	18	23	8	6	7	6	4	10	41
Femoral	8	10	7	3	2	3	2	1	18
Total	686	950	694	353	210	163	140	76	1,636

PAD, partial axonal degeneration; TAD, total axonal degeneration; EMG, electromyography.

Grade 0 muscle strength reduced from 42.4% to 24.3% and the ratio of Grade 5 muscle strength increased from 4.6% to 23.9%.

Simple decompression was performed in 323 (35%) of 921 nerve lesions which caused by gunshot wounds and improvement was observed 265 (82%) of them (Table 6). Among the improved lesions, the nerve was in-continuity in 246 (93%) lesions and discontinued in 19. Improvement was not observed in other 58 nerve lesions of which the nerve was interrupted in 43 and intact in 15 lesions. Nerve anastomosis (end-to-end or nerve grafting) was performed in 300 (32.5%) of 921 nerve lesions. Improvement was observed only in

TABLE 4. *Timing and technique of surgery*

Nerve	Time of Surgery (Months)			Types of Surgery					Total
	Min	Mean	Max	SD	PNE	EEE	EEIF	SG	
Median	1	3	24	152	95	91	108	83	529
Ulnar	1	3	11	78	50	105	91	71	395
Radial	1	4	24	73	37	29	31	28	198
Axillary	1	4	13	1	1	5	0	4	11
Musculocutaneous	2	3	7	5	0	0	0	3	8
Subscapular	4	6	11	2	0	0	0	0	2
Brachial plexus	3	4	14	35	24	19	38	10	126
Lumbosacral plexus	6	8	12	3	2	0	0	0	5
Sciatic	2	4	6	52	26	32	37	29	176
Peroneal	1	4	24	27	24	39	24	13	127
Tibial	1	2	4	17	15	3	0	6	41
Femoral	1	2	3	10	0	4	4	0	18
Total				455	274	327	333	247	1,636

Min, minimum; Max, maximum; SD, simple decompression; PNE, partial neuroma excision; EEE, end-to-end epineural anastomosis; EEIF, end-to-end interfascicular anastomosis; SG, interfascicular anastomosis with sural nerve graft; Time of Surgery, Time interval between the injury and the operation.

TABLE 5. *Postoperative clinical and electrophysiological results*

Nerve	EMG			Muscle Strength Grading						Total
	PAD	TAD	Normal	0	1	2	3	4	5	
Median	198	175	156	133	92	88	64	63	89	529
Ulnar	165	140	90	91	69	68	45	21	101	395
Radial	70	56	72	44	32	28	17	19	58	198
Axillary	3	5	3	3	2	1	1	1	3	11
Musculocutaneous	3	3	2	2	1	1	1	1	2	8
Subscapular	1	1	0	1	0	1	0	0	0	2
Brachial plexus	56	37	33	33	30	9	11	8	35	126
Lumbosacral plexus	4	0	1	0	0	2	1	1	1	5
Sciatic	75	58	43	55	30	16	18	17	40	176
Peroneal	37	43	47	24	23	14	6	11	49	127
Tibial	15	19	7	8	5	7	11	3	7	41
Femoral	6	5	7	4	1	3	1	2	7	18
Total	633	542	461	398	285	238	176	147	392	1,636

PAD, partial axonal degeneration; TAD, total axonal degeneration; EMG, electromyography.

TABLE 6. *The type of surgery and the type of injury*

	SD	PNE	EEE	EEIF	SG
Gunshot wound	323	201	132	168	97
Sharp laceration	88	26	85	112	26
Fracture	23	22	87	34	7
Traction	12	15	14	12	30
Iatrogenic	8	7	6	5	61
Others	2	2	3	2	26

SD, simple decompression; PNE, partial neuroma excision; EEE, end-to-end epineural anastomosis; EEIF, end-to-end interfascicular anastomosis; SG, interfascicular anastomosis with sural nerve graft.

32 (12%) lesions.

The most electrophysiological improvement was observed in femoral nerve lesions (NL) (39%) followed by peroneal NL (37%), and radial NL (36%). Good recovery was observed in cases in which the nerve shows continuity or non-complete transection, moderate or poor outcomes were observed in cases with neuroma-in-continuity or complete irregular transections such as gunshot injuries. Nerve grafting or long distance between the nerve stumps are also negative factors for surgical outcomes.

DISCUSSION

The diagnosis of peripheral nerve injuries employs techniques common to other disease states such as an accurate history, a careful inspection, and a thorough physical examination of the limb(s) involved, as well as selection of proper laboratory, radiologic and electrophysiologic tests for confirmation. In addition, however, knowledge of the anatomy of the limb and thus the ability to localize as well as reconstruct the nature of the injury or disease affecting the nerve are of paramount importance (Kline 1996).

The nature of peripheral nerve demands a complex reparative process after nerve division. The goal of nerve repair is to bring the proximal and distal ends of the nerve, the fascicles, or the fascicle groups together into close apposition without tension. Regarding axons from the proximal stump must cross the anastomosis and find their way down the endoneurial tubes of the distal nerve to reach the appropriate end organs-sensory receptors or motor end plates. Clinical recovery will result only if axons grow down the proper endoneurial tube (McGillicuddy 1996). A tension-free repair is necessary for adequate and functional anastomosis. Elasticity of a nerve trunk allows an increase of about 6% of its free length by streching. Beyond this limit, ischemia and internal disruption of the nerve occur (Seddon 1975). We not performed tension to the nerve during the surgical repair and we used sural nerve graft for the nerve defects which could not be unified with classic anastomosis.

If the gap between proximal and distal stumps is not sufficient for end-to-end anastomosis, a nerve graft is necessary for the repair. Use of autogenous interfascicular grafts to repair nerve injury that required suture have been described by Milesi et al. (1976). In most instances, autogenous nerve grafts have reserved for injuries with large defects where direct end-to-end suture was not possible (Singh et al.1992). In the literature data, good results were obtained in sural nerve cable graft anastomosis, varies from 68 to 90% (Levinthal et al. 1977; Brunelli and Brunelli 1979). The ideal nerve graft must cover the cross-sectional area of the nerve fascicles and must survive intact. The sural nerve is the common donor nerve. It furnishes a long graft (20 to 30 cm) with little resultant neurological deficit. We used sural nerve graft for end-to-end anastomosis in 247 of 1,636 nerve lesions.

Although accepted surgical techniques for peripheral nerve repair remain largely unchanged over the past three decades, much progress has been made in understanding the mechanisms involved in nerve regeneration, and consequently in providing additional measures to enhance this regenerative progress. (Haase et al. 1980; Kempe 1986; Brunelli and Brunelli 1990; Harris and Tindall 1991). Judgement of choosing the repair techniques also progressed parallely with this study. Epineurial repair, the standart method of nerve repair for many years, still has a prominent place in nerve injuries today (Myles et al. 1992). But interfascicular repair is most useful in nerves with a few large fascicles. In general, fresh, clean-cut nerve injuries are best treated by primary epineurial repair, especially if the cut ends show a very similar fascicular pattern.

Since peripheral nerve injury has no fatal course but a spectrum of morbidity, appropriate repair of injured nerve is important in remaining life of the patient. A surgeon, who is studying on peripheral nerve surgery, should make the best technical approach to achieve the possible recovery. In addition, the nerve repair must always be performed under magnification.The microsurgical techniques and interfascicular nerve grafting offer the best chances to get success in peripheral nerve repair (Bratton et al. 1979; Kline and Hudson 1990). We used operating microscope and microsurgical techniques in all cases for the best clinical result.

Gunshot wounds constitute a surgical dilemna in treament, because a near miss and the shock wave that momentarily deforms the nerve often cause the nerve deficit. This type of injuries cause open wounds. These wounds are a frequent cause of nerve lesion. The degree of damage may vary, but a high percentage suffer complete or partial division (Sunderland 1978). The gunshot wounds cause extensive crushing, tearing and contusion of the soft tissues such as muscle, tendon and nerve. In this type of injury, definition for changes in nerve is neuropraxia. One should be remainded that if the injuring agent pursues an oblique course through the soft tissues, the surface wound may be at some distance from the lacerated nerve. In injuries associated with extensive contusions or tearing of nerve fibers, as can occur with gunshot wounds or similar agents, the repair must be delay for 3 to 4 weeks, so that the extent of the pathologic change may be more readily defined under operating microscope and only normal fascicles apposed during nerve repair. Gunshot wounds are the major cause of injury in our series with a ratio of 56.3%. We performed late surgery for all of nerve lesions caused by gunshot wounds, and the necrotic tissues around the nerve lesions were also removed during the surgery to decompress the nerve. The factors affecting the postoperative results in this group of injury are the technique of surgery the continuity of the nerve. More improvement was observed among the patients with gunshot wounds who underwent simple decompression. The nerve lesions in which the nerve was intact, the improvement was more satisfactory than the lesions without continuity.

In conclusion, all types of peripheral nerve injury create different problems for neurosurgeons. Simple decompression is the most useful technique to improve the nerve lesion if there is no transection. The nature of each lesion must be evaluated in detail either clinically and electrophysiologically. After the accurate diagnosis, the neurosurgeon must choose the appropriate technique to repair the nerve.

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