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PERIPHERAL NERVE REPAIRS BY THE FUNICULAR SUTURE TECHNIQUE

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Sixty-one peripheral nerve repairs in 48 patients sutured by the funicular suture technique were followed up for a minimum of 2 years after operation, the average follow-up period being 48 months. Useful recovery was obtained in 100 per cent of cases with radial and musculocutaneous nerve repairs. Seventy-five per cent of cases with median, 82 per cent with ulnar and 88 per cent with digital nerve lesions attained the 'useful' grade of recovery. In the lower extremity, the motor recovery was excellent, whereas the sensory recovery was poor. In two out of three cases where cable grafting was performed between important funiculi the result obtained was excellent. To obtain satisfactory neurological recovery, the funicular suture technique using the surgical microscope is the method of choice for primary and secondary nerve suture and cable grafting.

Key words: microsurgery; peripheral nerves; funicular suture technique

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The epineurial nerve suture has been used as the routine method for repairing severed nerves. The functional recovery, however, has not been entirely satisfactory. Malalignment of the funicular patterns at the suture surfaces is believed to be the main factor causing poor recovery (Edsharge 1964, Bora 1967, Goto 1967, Hakstian 1968). To achieve their accurate approximation, Langley & Hashimoto 1917 and Sunderland (1953) advocated the funicular suture technique from the anatomical standpoint. It was the experimental work of Ito & Ishikawa in 1964 which first indicated that nerve repair by the funicular suture technique was feasible in clinical practice and gave excellent results. Since that time, we have employed this method of nerve repair using microsurgical techniques.

The purpose of this paper is to present the follow-up results of nerve repairs sutured by this method.

MATERIAL AND METHODS

Patients

Ninety injured nerves in 70 patients were repaired by the funicular suture technique. The details are given in Tables 1 and 2. The ages of the patients ranged from 2 to 68 years. Of the 70 patients, 48 (61 nerves) were followed up for a minimum of 2 years. The average follow-up period was 48 months. Three cases of cable grafting were included in this series.

Table 1. Survey of nerves sutured and followed up.

Nerve	No. of nerves repaired	No. of nerves followed up
Radial	9	5
Median	21	11
Ulnar	35	20
Musculocutaneous	2	2
Digital	16	16
Tibial	2	2
Peroneal	5	5
Total	90	61

Table 2. Details of injured nerves.

	Patients	
Primary suture		3
Secondary suture		67
Within 1 month	6	
Within 3 months	26	
Within 6 months	19	
Within 1 year	12	
Over 1 year	4	
Single nerve lesion		52
Two nerve lesions		16
Three nerve lesions		2
Total		70

Surgical technique

The funicular suture was performed as follows: Under the surgical microscope, preparatory trimming of the severed nerve ends was carefully carried out, using a razor blade, as far as the unscarred level of the nerve trunk, at which point the funiculi were caused to project from the cut surface. Then, the funicular pattern at the cut end was sketched on paper. This sketch is useful for the orientation and identification of funiculi to be sutured. Sunderland (1945, 1972) has already published precise maps of funicular patterns of the main nerves. Tamura (1969) and Urushidani (1974) in our department have also described the intraneural topographic atlases of the main nerves in the upper and lower extremities for clinical application. In addition to the position, shape and size of the funiculi, these maps assist in locating the functionally important funiculi and in identifying the corresponding funiculi to be approximated.

After the funicular identification, both nerve ends were secured with two epineurial sutures about 180 degrees apart, approximating the nerve ends without distorsion or twisting. A fine silk suture of 8–0 with an atraumatic needle was passed through the epineurium and then the perineurium of the funiculus to be sutured. The same procedure was performed on the opposite stump in a figure–0 or figure–8 as shown in Figure 1. A complete circumferential repair usually required a total of six to ten stitches for a satisfactory alignment of both funicular ends. Throughout the procedure, it is

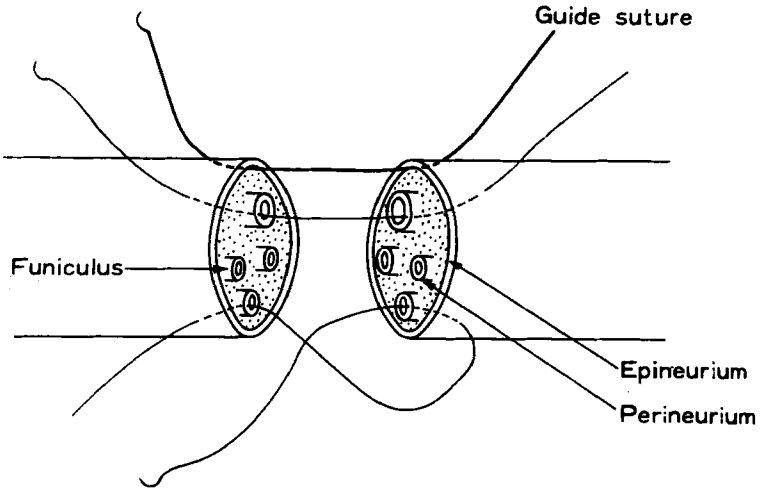

Figure 1. Schematic representation of the funicular suture technique employed by us.

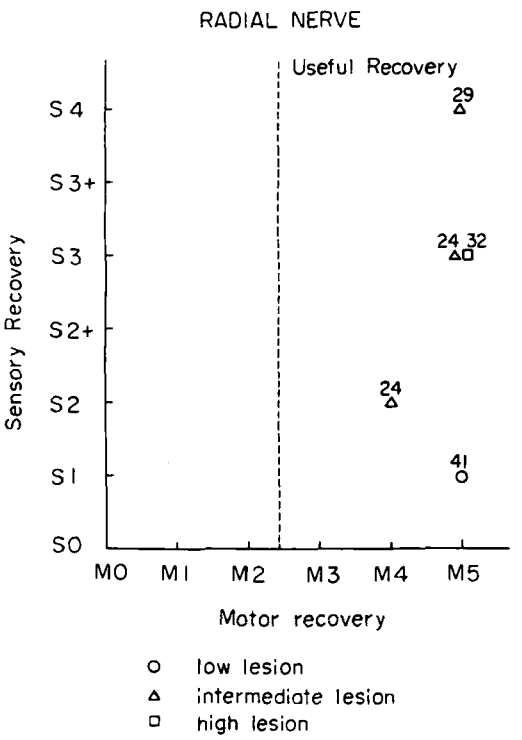

Figure 2. Follow-up result of radial nerve repairs. Numbers adjacent to symbols indicate the period of follow-up in months.

important that the epineurium and the perineurium are the only tissues to be pierced by suturing.

In large nerve trunks containing many funiculi, the functionally important funiculi, particularly those situated at the marginal region of the cut surface, were opposed.

Cable grafting was performed when the surgical gap could not be overcome by either mobilization and/or transposition of the nerve or joint flexion of less than 90° in the elbow. The grafting was carried out between important funiculi located with the aid of the intraneural topographic atlases.

Evaluation

The degrees of motor and sensory recovery in each nerve of the upper extremity were assessed by the criteria described by Sakellarides (1962), a system in which the recovery is classified from M0 to M5 for the motor function and from S0 to S4 for sensory function. The classification 'useful' for recovery of hand function was assigned according to Zachary's method (1954).

In sciatic and peroneal nerve lesions, the recovery was evaluated on the grading system reported by Clawson & Seddon (1960).

Each nerve lesion was divided into three categories: high, intermediate and low.

FOLLOW-UP RESULTS

All the five cases of radial nerve repairs which were followed up for a minimum of 2 years recovered almost normal motor function as is seen in Figure 2. Six out of eight cases of median nerve repairs obtained useful recovery of function (Figure 3). It is emphasized that two out of the three high lesions of the median nerve were within the range of useful recovery and the remaining case could be judged as almost useful because its recovery was classified as M2 and S2+. Out of 17 ulnar nerve repairs, 14 attained useful recovery of function, while the remaining three were near this level of recovery (Figure 4). In patients with combined median and ulnar nerve lesions, one out of three attained a satisfactory degree of recovery. Two musculo-

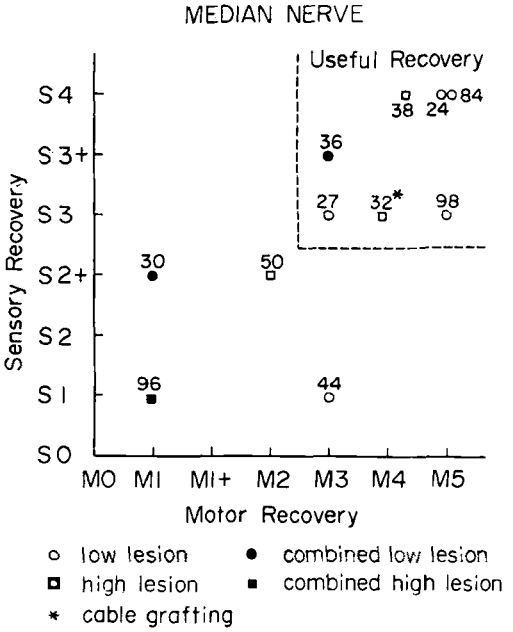

Figure 3. Follow-up result of median nerve repairs.

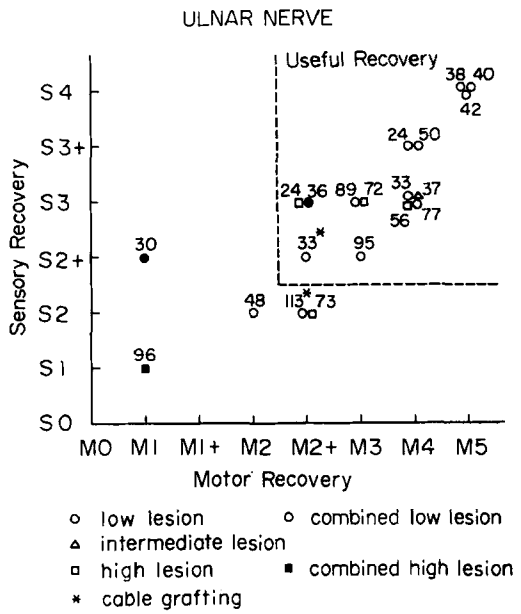

Figure 4. Follow-up result of ulnar nerve repairs.

cutaneous nerve lesions showed an excellent return of function, evaluated by the same criteria. All digital nerve sutures except two achieved satisfactory return of sensation; over S2+.

In seven cases of nerve suture in the lower extremity, the sensory recovery was satisfactory in all cases. The motor function, however, recovered to the grade "good" in only one out of five patients with sciatic nerve repair and one out of two with tibial nerve repair.

Table 3 gives the details of the three cases of cable grafting, of whom two achieved useful recovery of hand function.

DISCUSSION

The follow-up study revealed that the funicular suture technique was able to bring about a satisfactory recovery of function in the repaired nerves. 'Useful' recovery was enjoyed by 100 per cent of patients with radial and musculocutaneous nerve lesions. In median, ulnar and digital nerve lesions, 75 per cent, 82 per cent and 88 per cent of repaired cases, respectively, attained useful recovery, the remainder demonstrating a function close to the 'useful' grade.

The results obtained in this series appear to be better than those obtained by the traditional suture method (Nicholas & Seddon 1957, Larsen & Posch 1958, Sakellarides 1962, Seddon 1972). The results indicated that the more simple the funicular pattern the better the recovery. It is also possible that nerve repairs of low level and/or single lesions achieved better results than those of high level and/or combined lesions.

The funicular suture technique improved not only the quantity but also the quality of the nerve regeneration. A reduced initial delay, an increased rate of axon growth and a rapid return of function were observed in nerves repaired by this technique. Figure 5 depicts the advancement of Tinel's sign in representative cases.

Bora (1967), Hakstian (1968) and Grabb et al. (1970) have reported the superiority of the funicular suture over the epineurial suture. The same conclusion was confirmed by histological and

Table 3. Cable grafting.

Case no.	Age	Sex	Nerve	Level	Surgical gap (cm)	Follow-up period (months)	Result
1	25	female	Median	Elbow	12	32	M4, S3
2	42	female	Ulnar	Wrist	3	113	M2+, S2
3	17	male	Ulnar	Forearm	12	33	M2+, S2+

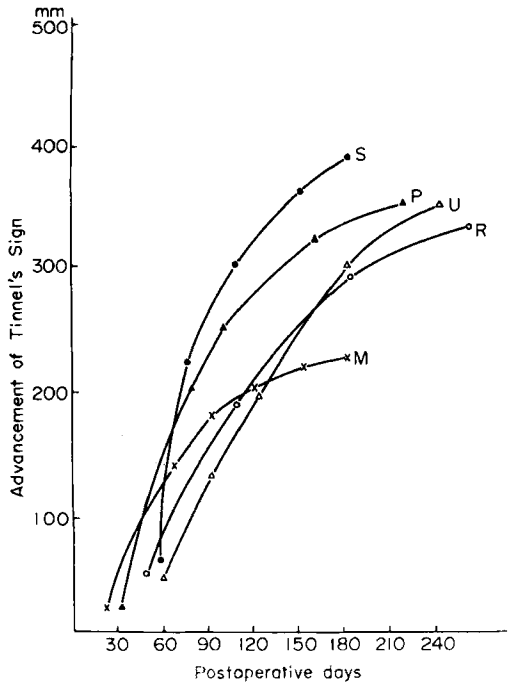

Figure 5. Advancement of Tinel's sign in repaired nerves. R: radial nerve; M: median nerve; U: ulnar nerve; P: peroneal nerve; S: sciatic nerve.

electrophysiological studies conducted by Ishikawa (1966), Goto (1967) and Yamamoto (1974) in our department (Figure 6).

The funicular pattern within a nerve only remains constant for a maximum of 15 millimeters because of the plexus formation of the funiculi (Sunderland 1970). Thus, a discrepancy in the funicular pattern may be inevitable in the approximating surfaces. However, the orientation and identification of the funiculi to be sutured are not always difficult in practice, since certain funiculi with important functions have particular localizations in the cross sections at certain levels of a nerve trunk (Tamura 1969, Urushidani 1974). In addition, all the funiculi are not simultaneously involved in plexus formation at the same level (Sunderland 1970). Thus, a successful connection can be expected in at least some funicular groups even if the corresponding funiculi are not completely opposed. Identification of funicular

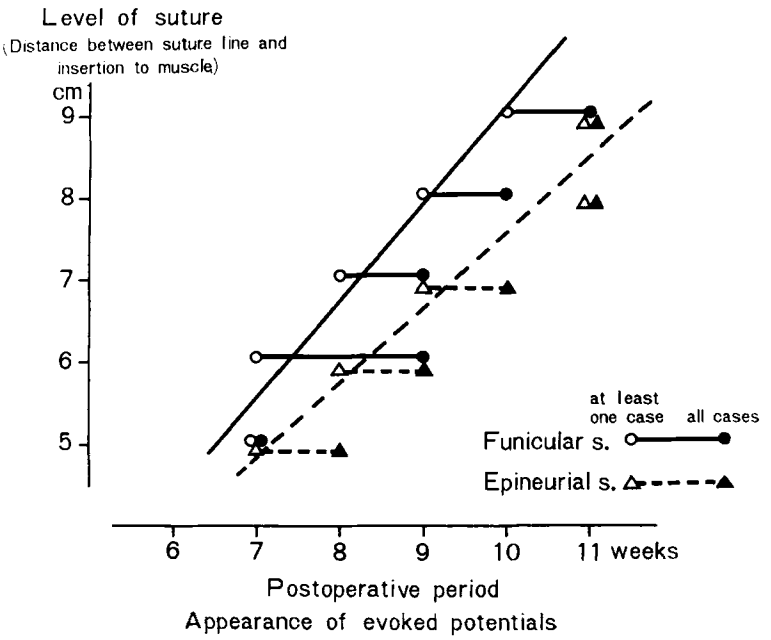

Figure 6. Appearance of evoked potentials after nerve suture in the peroneal nerves in dogs. More rapid and more complete recovery of the function is observed in the funicular suture at each level of repair, compared with the epineurial suture.

function by electrical stimulation (Hakstian 1968, Vandeput et al. 1969, Grabb et al. 1970) is presumably ideal but is time consuming and restricted, in practice, to the primary suture.

The less satisfactory result following peroneal nerve sutures is considered to be caused by the peculiarity of the funicular pattern at the level of the fibular head, where the funiculi are composed of intermingled motor and sensory axons (Urushidani 1974). This is also true in nerve lesions at a high level. The poor result in combined lesions may result from associated extensive damage to soft tissue and blood vessels.

The surgical gaps could usually be closed without pronounced tension. No significant difference in the follow-up results was found between various closure distances, although the number of cases appears to be too limited to draw such a definite conclusion as did Millesi et al. (1972 a, b).

Conclusion

From the results of clinical and experimental investigations, it is concluded that the funicular suture technique using the surgical microscope is the method of choice for peripheral nerve repair. It is stated that primary suture and nerve grafting are the absolute indications for the application of this microsurgical technique. Even in secondary nerve suture, repairs by the funicular suture technique also achieved an excellent recovery of the nerve function, when compared with the results of epineurial suture.

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