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NERVE REPAIR IN CIVIL PRACTICE RESULTS OF TREATMENT OF MEDIAN AND ULNAR NERVE LESIONS

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The results of nerve repair carried out in Great Britain during the second world war have been analysed and reported by the Nerve Injuries Committee of the Medical Research Council in "Peripheral Nerve Injuries" (1954). This report is often referred to, and for the sake of brevity is described as the P.N.I. Report.

Most of the patients treated in the wartime nerve injuries centres suffered injuries that were a direct result of war, but in some cases the injuries were the same as those encountered in civil life, such as lacerations with broken glass. The latter were too few to be compared with the war injuries, but it seemed likely that the results of treatment were better. Civil wounds are for the most part cleaner and less extensive, secondary suture can be undertaken earlier, the loss of nerve tissue is less, and the resection required is shorter. Both of these factors have been shown to give better results (P.N.I. Report, p. 367).

Sufficient time has now elapsed for the accumulation of a series of repairs following civil injuries, and, as the median and ulnar nerves are by far the most commonly involved, this study is confined to the results of repair of these nerves. The results of digital nerve repair are excluded.

Cases Available for Assessment

1. *Cases of Civil Injury Treated at the Oxford Nerve Injuries Centre from 1941 until 1948* (this unit was transferred to the Royal National Orthopaedic Hospital in 1948).—The records of the Oxford cases were available and a number of the patients attended for re-examination.

2. *Patients Treated at the Royal National Orthopaedic Hospital from 1948 until the End of 1954*.—Cases due to gunshot and similar wounds have been excluded.

3. *Cases of Primary Suture, for the most part Performed Elsewhere and Referred for Supervision*.—A number of patients in whom primary suture had been performed were referred because recovery had been poor and secondary suture was carried out. For this reason the results of primary nerve suture in this series do not give an exact picture of the reliability of the operation.

The number of cases followed up is shown in Table I. These figures do not represent the relative incidence of single and combined nerve injury. In a number of cases in which both nerves had been injured and repaired the

TABLE I.—Cases Available for Analysis

Nerve	Sutured Alone	Both Nerves Repaired	Total	Total Repairs	Total Patients
Ulnar	135	28	163	} 305	277
Median	114	28	142		

patients were referred for further treatment following failure of suture in only one of them, and consequently only one was resutured.

Method of Analysis of Recovery

The method of analysis of recovery recommended in the P.N.I. Report has been followed without modification, except that cases in which less than three years has elapsed since the time of repair have been included. The patients who attended for re-examination were examined by one of us (O. R. N.) with the assistance of Dr. Constantin Schuler, of Zurich. Thus they were examined by two observers, neither of whom had carried out any of the operations in this series.

Duration of Post-operative Observation

Recovery was not considered maximal until at least three years had elapsed since the time of repair. Cases in which less than three years had elapsed since the time of repair were included in the tables in order to show the grade of recovery that could be expected in the earlier years. This may be of assistance in deciding whether a sutured nerve should be re-explored. Patients who were followed for less than one year have been excluded. A total of 132 repairs have been followed up for five to fifteen years.

Lapse Rate

The lapse rate for cases in which a three-year follow-up was possible is shown in Table II. A number of patients who failed to attend were operated on towards the end of the Oxford period and were unable to travel the extra distance to London for re-examination.

TABLE II.—Lapse Rate at Three Years

Nerve	Total Cases	Repaired More than 3 Years Previously	Follow-up at 3 Years	Lapse Rate
Ulnar	163	142	103	39/142 (36.4%)
Median	142	119	95	24/119 (20.8%)

As in the P.N.I. Report, all lapsed cases have been excluded from the analysis year by year. In view of the number of patients achieving a useful grade of recovery in less than three years it was tempting to include them in the final analysis and to present two possible extremes of recovery rate, in the first assuming that *all* lapsed cases had failed to show further recovery, and in the second assuming that *all* lapsed cases recovered satisfactorily. This method, however, was not adopted so that it might be possible to compare the results in the present series directly with those in the P.N.I. Report. It is even more probable in the present series than in those described by Zachary in the Report that this has resulted in an underestimate of the proportion of recoveries, because civilians seem less likely to continue to report if recovery is satisfactory than pensioners, who are required to attend for periodic re-examination.

Grading of Recovery

Sensory Recovery.—This is designated by the letter S followed by a figure for the grade of recovery. 0=absence of sensibility in the cutaneous zone supplied exclusively by the nerve concerned (the autonomous zone). 1=recovery of deep cutaneous pain within the autonomous zone. 2=return of some degree of superficial pain and tactile sensibility within the autonomous zone. 2+=return of tactile and pain sensibility throughout the autonomous zone but with persistent overreaction. 3=return of superficial pain and tactile sensibility throughout the autonomous zone with the disappearance of overreaction. 3+=as for grade 3, with good localization of stimuli and some return of two-point discrimination. 4=complete recovery.

Motor Recovery.—This is designated by the letter M followed by a figure for the grade of recovery. 0=no contraction. 1=return of perceptible contraction in the forearm muscles. 1+=*median*: forearm muscles able to contract against gravity but paralysis of the thenar muscles; *ulnar*: forearm muscles able to contract against gravity but paralysis of the ulnar intrinsic muscles of the hand. 2=*median*: forearm muscles able to contract against gravity and feeble action in the thenar muscles; *ulnar*: forearm muscles able to contract against gravity and some power in the hypothenars, but little or none in the interossei. 2+=*ulnar only*: forearm and hand muscles all active, but the first dorsal interosseous unable to contract against resistance. 3=*median*: forearm and thenar muscles able to contract against resistance; *ulnar*: forearm muscles, hypothenars, and first dorsal interosseous able to contract against resistance. 4=*median*: all muscles able to contract against strong resistance with some independent action; *ulnar*: all muscles able to contract against resistance with some independent lateral movement of fingers. 5=full recovery in all muscles.

Useful Grade of Recovery in Relation to Level of Injury

The useful grade of recovery for each nerve was defined in the P.N.I. Report and has been followed here. The following have been adopted as definitions of the level of injury:

Nerve	Proximal	Intermediate	Distal
Ulnar	Above branches to flexor carpi ulnaris	Between branches to flexor carpi ulnaris and flexor digitorum profundus	Distal to branches to flexor digitorum profundus
Median	Above branches to pronator teres	Between branches to pronator teres and flexor pollicis longus	Distal to branch to flexor pollicis longus

Ulnar Nerve.—The useful grade of recovery in distal and intermediate repairs is that in which all the hand muscles are active (M2+) and there is return of tactile and pain sensibility throughout the autonomous zone but with overreaction (S2+).

Median Nerve.—The useful grade of recovery in distal and intermediate repairs is that in which the thenar muscles are able to contract against resistance (M3) and there is return of tactile and pain sensibility throughout the autonomous zone but with overreaction (S2+).

After proximal repairs return of power in the long flexor muscles (M1+) is regarded as a useful grade of recovery—that is, sufficient to warrant the performance of the operation.

For the purposes of analysis of recovery all patients in whom the muscles are able to contract against strong resistance with some independent action (M4), and where there is good localization of stimuli and some return of two-point discrimination (S3+), are considered as one group. Patients showing no recovery are grouped with those in whom recovery is so slight as to be valueless.

The Injuries

Types of Wound.—Most of the wounds were lacerations and were usually caused by broken glass—milk bottles, windows, and glass doors. This accounted for 287 nerve injuries (94%). Incised wounds caused by a knife or similar instrument accounted for only 14 (4.6%). Traction caused disruption of a nerve in two cases (0.7%), while compression causing a lesion in continuity, for which resection and suture was carried out, accounted for a further two (0.7%).

Associated Injuries.—(a) Other nerves. In 45 of the 142 median nerve lesions (31.3%) the ulnar nerve was also involved to some extent, while in 33 of the 163 ulnar nerve lesions (20.2%) the median nerve was also involved. (b) Significant tendon injury—that is, involving the long tendons of the digits—was present in 85 of the 142 median nerve lesions (59.9%) and 66 of the 163 ulnar nerve lesions (40.5%). (c) Fractures occurred in nine of the median cases and five of the ulnar cases. (d) Sepsis of a degree greater than slight redness of the skin edges occurred in only three cases (1.08%) following the primary treatment of the wound and in none following second suture.

Results of Repair of Ulnar Nerve

In this series there was a great preponderance of distal repairs of the ulnar nerve, whereas in the series presented in the P.N.I. Report nearly one-third of the sutures were proximal. Consequently no comparison of the two complete series is admissible.

Distal Repairs

Table III shows the return of motor function after all distal repairs of the ulnar nerve irrespective of the gap after resection and of the delay before repair. A useful grade of

TABLE III.—Ulnar Nerve. Distal Repair; Motor and Sensory Recovery

Grade of Recovery	Follow-up in Years											
	1			2			3			5		
	No.	%	C%	No.	%	C%	No.	%	C%	No.	%	C%
M4	6	4.6	4.6	18	16.7	16.7	25	28.8	28.8	21	35.0	35.0
M3	20	15.4	20.0	36	33.4	50.0	28	32.2	61.0	19	31.7	66.7
M2+	39	30.0	50.0	28	25.9	76.0	16	18.4	79.4	9	15.0	81.7
M2	60	46.2	96.2	24	22.2	98.2	15	17.3	96.7	10	16.8	98.5
M1	5	3.8	100.0	2	1.8	100.0	3	3.3	100.0	1	1.5	100.0
Total	130			108			87			60		
S3+	6	4.7	4.7	12	11.4	11.4	13	15.3	15.3	12	21.1	21.1
S3	35	27.1	31.8	46	43.8	55.2	41	48.2	63.5	27	47.4	68.5
S2+	29	22.5	54.3	23	21.9	77.1	16	18.8	82.3	8	14.0	82.5
S2	59	45.7	100.0	24	22.9	100.0	15	17.7	100.0	10	17.5	100.0
Total	129			105			85			57		

C% = Cumulative percentage throughout tables.

recovery (M2+) occurred in 81.7% of cases, while no less than 35% regained some independent lateral movement of the fingers (M4).

The incidence of useful recovery may be compared with that in the most favourable group of distal ulnar sutures in the P.N.I. Report (delay before operation less than six

months and a gap of less than 5 cm.—Table 91, p. 378). This is to some extent weighting the balance against the present series, because not all the lesions in the latter were distal, not all the gaps were short, and not all the repairs were undertaken within less than six months from the time of injury. There was useful recovery in 78.5% of the cases in Table 91, and 16% regained some independent lateral movement of the fingers. The overall recovery rate is not significantly better in the present series, but the proportion regaining independent movement is higher—35%. A further breakdown of the present series in order to make the groups exactly comparable is not warranted and would confuse the general aim of presenting the average grade of recovery that may be expected after the average type of civil injury. The results are shown graphically in Fig. 1.

FIG. 1.—Ulnar nerve. Distal repair; motor recovery. Compares Table III with the P.N.I. Report, Table 91.

Useful sensory recovery (S2+) occurred in 82.5% of cases, and 68.5% reached grade S3—that is, overreaction was absent (Table III). These figures compare with 64.6% reaching grade S2+ and 49.5% reaching grade S3 in the most favourable group of the P.N.I. Report series (Table 92, p. 379). The results are significantly better in the present series, and are shown graphically in Fig. 2.

FIG. 2.—Ulnar nerve. Distal repair; sensory recovery. Compares Table III with P.N.I. Report, Table 92.

The results may be summarized by saying that four out of five distal repairs of the ulnar nerve led to a useful sensory and motor recovery; two out of three reached the grade of sensory recovery in which there was no overreaction; one case in three showed some independent finger movement. However, the independent finger movement was never perfect, and was usually readily apparent only in the index finger. Even so, it materially improved the function of the hand.

Intermediate Repairs

The number in this group is small and cannot be compared with the distal repairs, but seven out of eight patients who attended at the end of three years had made an adequate motor recovery and five out of nine an adequate sensory recovery. This discrepancy in numbers is due to all the intrinsic muscles of the hand being innervated by the median nerve in one patient (Table IV).

TABLE IV.—Ulnar Nerve. Intermediate Repair; Motor and Sensory Recovery

Grade of Recovery	No. Followed-up in Year			
	1	2	3	5
M4				
M3				
M2+	2	8	5	2
M2	7			
M1+	2	1	1	1
Total ..	11	11	8	6
S3+				
S3	2	3	4	3
S2+	1	4	1	
S2	9	5	4	4
Total ..	12	12	9	7

Proximal Repairs

The number in this group is also small, but at the end of three years all patients had made an adequate motor recovery—that is, the long flexor muscles contracted against gravity—and indeed seven of the nine patients showed useful recovery in the intrinsic muscles of the hand and six had made an adequate sensory recovery (Table V).

TABLE V.—Ulnar Nerve. Proximal Repair; Motor and Sensory Recovery

Grade of Recovery	No. Followed-up in Year			
	1	2	3	5
M4		1	2	
M3		2	2	3
M2+		4	3	2
M2	7	2	1	1
M1+	6	2	1	1
Total ..	13	11	9	7
S3+			1	
S3	2	2	4	4
S2+		2	1	
S2	11	7	3	3
Total ..	13	11	9	7

Results of Repair of Median Nerve

As with the ulnar nerve, a satisfactory comparison can be made only of the results of distal repair.

Distal Repairs

Table VI shows the return of motor function in all cases of distal repair of the median nerve irrespective of the gap

TABLE VI.—Median Nerve. Distal Repair; Motor and Sensory Recovery

Grade of Recovery	Follow-up in Year											
	1			2			3			5		
	No.	%	C%	No.	%	C%	No.	%	C%	No.	%	C%
M4	9	7.9	7.9	24	24.5	24.5	31	35.6	35.6	20	38.5	38.5
M3	29	25.7	33.6	28	28.6	53.1	24	27.6	63.2	14	26.9	65.4
M2	42	37.2	70.8	31	31.6	84.7	21	24.1	87.3	11	21.1	86.5
M1+	33	29.2	100.0	15	15.3	100.0	11	12.7	100.0	7	13.5	100.0
Total	113			98			87			52		
S3+	4	3.4	3.4	9	8.9	8.9	13	14.8	14.8	13	24.6	24.6
S3	24	20.2	23.6	30	29.4	53.3	37	42.0	56.8	21	39.6	64.2
S2+	25	21.0	44.6	27	26.4	64.7	16	18.2	75.0	8	15.1	79.3
S2	66	55.4	100.0	36	35.3	100.0	22	25.0	100.0	11	20.7	100.0
Total	119			102			88			53		

C% = Cumulative percentage throughout tables.

after resection and of the delay before repair. A useful grade of recovery (M3) was obtained in 65.4% of cases compared with 42.6% in the most favourable group of distal median sutures in the P.N.I. Report (delay less than six months and gap less than 5 cm.—Table 93, p. 379). The results are shown graphically in Fig. 3.

FIG. 3.—Median nerve. Distal repair, motor recovery. Compares Table VI with P.N.I. Report, Table 93.

Sensory recovery of a useful grade (S2+) occurred in 79.3% of cases and 64.2% reached the higher grade of S3—that is, overreaction was absent (Table VI). These figures compare with 68% reaching grade S2+ and 52% reaching grade S3 in the most favourable group of the P.N.I. Report series (Table 94, p. 380). The results in the present series appear slightly more favourable but are not significantly better (Fig. 4).

FIG. 4.—Median nerve. Distal repair, sensory recovery. Compares Table VI with P.N.I. Report, Table 94.

The results may be summarized by saying that two out of three distal repairs of the median nerve led to useful motor recovery, four out of five gave a useful grade of sensory recovery, while two out of three reached the grade of sensory recovery in which overreaction was absent.

It may seem that the results of median nerve repair are inferior to those of the ulnar, but the respective definitions of useful motor recovery are different. In the case of the ulnar nerve all muscles are required to be active—that is, contracting against gravity—and this, in the interossei, is useful. In the case of the median nerve the thenar muscles are, in addition, required to contract against resistance, as this power is essential in grasping.

Intermediate Repairs

The number in this group is small and cannot be compared with the distal repairs, but two of the three patients seen at the end of three years showed adequate motor and sensory recovery (Table VII).

TABLE VII.—Median Nerve. Intermediate Repair; Motor and Sensory Recovery

Grade of Recovery	No. Followed-up in Year			
	1	2	3	5
M4				
M3	2	3	2	1
M2	2	1	1	1
M1+	2			
Total ..	6	5	3	2
S3+			1	
S3	1		1	1
S2+	3	3	1	1
S2	1	2		
Total ..	5	5	3	2

Proximal Repairs

The number in this group is also small, but five of the six patients seen at the end of three years showed adequate motor recovery—that is, the long flexor muscles contracted against gravity, and adequate sensory recovery was present in three (Table VIII).

TABLE VIII.—Median Nerve. Proximal Repair; Motor and Sensory Recovery

Grade of Recovery	No. Followed-up in Year			
	1	2	3	5
M4				
M3	2	3	3	2
M2	1	2	2	2
M1+	2			
M1	4	2	1	1
Total ..	9	7	6	5
S3+			1	1
S3	2	2	2	1
S2+	7	4	3	3
S2				
Total ..	9	6	6	5

Factors Influencing Recovery

The factors influencing recovery considered in the P.N.I. Report (p. 366) were the level of injury, the delay before repair, and the extent of the gap to be closed. It was not considered justifiable to break down the series into groups corresponding to other factors. In the present series the nature of the wound was essentially the same throughout, and an attempt has been made to assess the effect of other factors.

Age

The age distribution of the combined group of 305 ulnar and median nerve repairs was: 0–10 years, 32 repairs; 11–20 years, 86 repairs; 21–50 years, 174 repairs; over 50 years, 13 repairs.

The numbers in each age group are smaller when cases operated on less than three years previously and lapsed cases are excluded, and too small for any significant deduction to be made on the influence of age on recovery, apart from patients in the 0–10 years group. Twenty-three distal repairs were carried out on 22 patients; sensory recovery was adequate in all, and in only one case was motor recovery defective. It may be just worth mentioning, though the figures are not strictly significant, that seven patients out of the 13 over 50 were followed for three years or more, and two showed adequate motor and four adequate sensory recovery.

Level of Lesion

The large number of proximal sutures described in the P.N.I. Report made it possible to demonstrate that the more

proximal the lesion the worse the prognosis. The influence of this factor cannot be assessed in the present series, but no further demonstration is necessary.

Extent of Gap

As might be expected the average gap after resection in this series was small. The figures are shown in Table IX.

TABLE IX.—*Distribution of Cases According to Gap After Resection*

Gap in cm.	Ulnar Nerve		Median Nerve	
	No.	%	No.	%
2.5 or less ..	91	56.2	52	36.6
2.6-5 ..	59	36.4	72	50.7
5.1-7.5 ..	11	6.8	10	7.1
Over 7.5 ..	1	0.6	8	5.6
Total No. ..	162 *	100.0	142	100.0

* In one case the gap was not recorded

It has been shown in the P.N.I. Report (p. 374) that a gap of over 5 cm. is prejudicial to recovery. For any given gap the mobilization required to permit satisfactory apposition of the nerve ends is more extensive in a child than in an adult; hence in comparing recovery in relation to the gap after resection only adults are considered—that is, patients over the age of 17 years. In distal repairs of the median nerve a higher proportion recovered after a short resection (up to 2.5 cm.) than after a longer one (2.6-5 cm.), but the groups are small and the difference is hardly great enough to be significant (Table X). There was no significant differ-

TABLE X.—*Median Nerve Recovery in Relation to Gap (Distal Repairs—Patients Over 17 Years)*

Gap in cm.	No. of Cases	No. Reaching M3	No. Reaching S2 +
2.5 or less {	30 motor 30 sensory	21 (70%)	26 (86.7%)
2.6-5 {	32 motor 33 sensory	16 (50%)	20 (60.6%)

ence between the two groups in distal repairs of the ulnar nerve (Table XI). In the ulnar nerve a more extensive gap may be overcome by anterior transposition of the nerve and there is little chance of intraneural changes occurring as a

TABLE XI.—*Ulnar Nerve Recovery in Relation to Gap (Distal Repairs—Patients Over 17 Years)*

Gap in cm.	No. of Cases	No. Reaching M2 +	No. Reaching S2 +
2.5 or less ..	42 (motor and sensory)	34 (80.9%)	33 (78.6%)
2.6-5 ..	26	21 (80.7%)	18 (68.9%)

result of post-operative stretching; but in the median nerve there is no comparable method of closing an extensive gap, and this may be the reason why the results of suture of the ulnar nerve are rather better than those of the median.

Extent of Mobilization

In cases in which there was a large gap the lower recovery rate might be due to: (1) disparity in size of the proximal and distal stumps of the nerve, making satisfactory suture difficult; (2) incongruity of the funicular pattern at the suture line; or (3) the adverse effect of mobilization of the nerve which was required in order to close the gap. It is possible that the nerve is partially devascularized by the mobilization, although it has been shown that adequate recovery can occur through free grafts of the ulnar to the median nerve (P.N.I. Report, Table 112, p. 406).

An answer to this question is provided by the results of median nerve suture at the wrist, for which alternative methods of mobilization are available for the closure of gaps of comparable extent. A gap of up to 2.5 cm. may frequently be closed by local mobilization of the nerve, flexing the elbow to 90 degrees and the wrist to 30-45 degrees. Alternatively, in order to allow the wrist to remain in the neutral position, full mobilization of the nerve to the

elbow may be carried out by division of the radial head of flexor sublimis digitorum and also, if necessary, reflection of the superficial head of pronator teres and mobilization of the branches of the nerve.

The numbers in the groups studied are small, but a higher proportion reached the higher grades of motor recovery after only local mobilization (Table XII). The grade of sensory

TABLE XII.—*Median Nerve. Effect of Mobilization on Recovery (Age Group 11-50. Gap up to 2.5 cm.)*

	No. of Cases	No. Reaching M4	No. Reaching S3
Local mobilization {	13 motor 14 sensory	10 (72.0%)	12 (85.7%)
Extensive mobilization {	9	2 (22.2%)	7 (77.7%)

recovery does not appear to be affected by the extent of the mobilization. This suggests that devascularization may to some extent impair recovery, and mobilization should not be more extensive than is necessary to close the gap without tension. In distal lesions of the median and ulnar nerves alike, a gap after resection of over 2.5 cm. will nearly always require full mobilization. This is described above for the median nerve; for the ulnar nerve, anterior transposition of the nerve at the elbow is required.

If further flexion, beyond the angles mentioned above, is required in order to close the gap harmful intraneural fibrosis is likely to develop as a result of stretching of the nerve in the post-operative period. The alternative, nerve grafting, may be preferable. In this series nerve grafts were used in the repair of seven ulnar and 19 median nerve lesions. The grafts were used (1) where the gap was too great to be closed by the usual methods of mobilization—21 cases; and (2) where there was a partial (funicular) lesion of the nerve—five cases. The results in this group are not presented, as they have already been reported by Brooks (1955).

Delay Before Repair

It has been shown in the P.N.I. Report that a delay before suture of over six months is prejudicial to recovery. The delay before repair in the present series is shown in Table XIII; 78.4% were repaired within six months, and

TABLE XIII.—*Ulnar and Median Nerves. Delay Before Repair*

Delay	No. of Repairs	Percentage
Up to 3 months ..	165	54.2
3-6 ..	74	24.2
6-9 ..	27	8.8
Over 9 ..	39	12.8
Total No. ..	305	

thus the factor of delay was not strongly operative. Adequate recovery may still occur if the delay before repair is more than six months; in ulnar nerve repairs 64.7% made an adequate motor recovery and 68.8% an adequate sensory recovery, while in median nerve repairs 56.7% made an adequate motor recovery and 67.7% an adequate sensory recovery (Table XIV). Although a long delay

TABLE XIV.—*Recovery in Cases Repaired After Six Months*

Nerve	No. of Cases	No. Reaching M2 + (Ulnar) M3 (Median)	No. Reaching S2 +
Ulnar .. {	17 motor 16 sensory	11 (64.7%)	11 (68.8%)
Median .. {	30 motor 31 sensory	17 (56.7%)	21 (67.7%)

before repair is undesirable, late repairs should still be done in the knowledge that a good return of function may be obtained in a reasonable proportion of cases. However, this is true only when most of the lesions are distal and the regenerating axons have therefore to traverse a short length of nerve.

Histological Grading

The nerve ends resected at the time of operation were usually examined histologically, and these findings have been investigated with a view to determining whether poor recovery could be correlated with the state of the resected stumps. It should, however, be noted that all the material in this series fulfilled the gross criteria of an adequate resection—i.e., there was no palpable induration of the nerve, the nerve bundles were easily distinguishable, and the epineurium was mobile.

The histological evidence of adequate resection is a normal arrangement of bundles in both stumps of the nerve and absence of *endoneurial* fibrosis. Perineurial fibrosis is unimportant. In most cases the resection was adequate, and where there was some degree of endoneurial fibrosis it was usually in the distal stump. This emphasizes the particular difficulty in deciding whether the distal resection is adequate. The proximal nerve bundles, which contain myelinated fibres, look like ground glass when cut across, but the distal bundles are much smaller, and, being devoid of nerve fibres, do not stand out so clearly from the interfascicular tissue. It is also likely that the sclerosing changes in the distal stump are more extensive as a result of ischaemia caused by interruption of the longitudinal blood supply (P.N.I. Report, p. 123).

When the cases of poor recovery after suture were examined there did not seem to be any histological feature to account for the failures.

Primary Suture

Sixteen primary sutures of the median nerve and 22 primary sutures of the ulnar nerve were seen in this series. Most of these cases had been operated on elsewhere; they had been referred for supervision and no resuture was performed. The results in patients with an adequate follow-up are summarized in Table XV.

TABLE XV.—Results of Primary Suture in Cases Followed Up for Three or More Years

Grade of Recovery	No. of Cases	Cumulative Percentage of Total Number
Ulnar nerve (16 cases):		
M3	8	50.0
M2+	4	75.0
S3	11	68.8
S2+	2	81.3
Median nerve (13 cases):		
M4	6	46.1
M3	3	69.2
S3	8	61.5
S2+	3	84.6

In this small group the proportion reaching the higher grades of recovery is not significantly better than in the total results, and only one case was seen of an exceptionally good recovery after primary suture.

There is then no reason to modify the previously published statement that early secondary suture offers equally good prospects of recovery and is best used routinely because of its greater reliability. Primary suture may be carried out in the rare clean incised wound where there is minimal tendon and soft-tissue damage. Nevertheless re-exploration of the suture site should be carried out if there are no definite signs of recovery by the end of six months or if a palpable neuroma develops at the suture site within this time. Further delay may be harmful. Yet even in these uncommon cases there are technical objections to primary suture. The fresh epineurium is often too thin to hold sutures securely, whereas by the time secondary suture is undertaken it is two to four times its normal thickness and holds sutures well. Furthermore, there may have been interstitial damage to the nerve, the extent of which cannot be determined at the time of injury but which is clearly manifest a few weeks later as palpable, and, on section, visible intraneural fibrosis.

It is unfortunate that, although primary suture still has its advocates, there is no series available for comparison in which a strict grading of the degree of recovery has been recorded.

Associated Tendon Injuries

Significant tendon injury occurred in almost half the cases in this series. The most satisfactory results were seen after the following programme of treatment. The flexor tendons are sutured immediately and the nerve ends simply approximated in their correct orientation. Every effort is made to obtain full mobility of the digits, the only treatment of the nerve injury being galvanic stimulation of the paralysed muscles of the hand to prevent progressive wasting. When the tendons are acting well a secondary nerve suture is performed. There is no disturbance of the tendons, because they lie deep to the nerves, and, for the same reason, movement of the fingers does not disturb the line of suture of the nerve. At the time of secondary suture the amount of nerve to be resected is readily ascertained and if the nerve ends have been approximated initially the gap after resection is minimal.

It is also worth mentioning that the surgeon, at the end of a long primary operation for tendon and wound repair, is less likely to perform a technically satisfactory nerve suture than when repairing the nerve alone at a secondary operation undertaken at leisure.

Summary

During the second world war surgeons in Great Britain who were specially devoted to the investigation and treatment of peripheral nerve injuries devised a precise method for the assessment of recovery, and the results, presented in the Report of the Nerve Injuries Committee of the Medical Research Council, are perhaps the most accurate that exist. The same method has now been applied in a study of the commonest nerve injuries encountered in civil practice, those of the median and ulnar nerves. This paper is concerned with the end-results of nerve suture after 305 repairs in 277 patients, most of whom had suffered injury in the region of the wrist. The period of post-operative observation was three years or more in 198 of the 305 sutures. Many patients made a good recovery within less than three years, and, for reasons that have been given, it is probable that the prognosis is rather better than that recorded in this paper.

In a high proportion of cases—94%—the injury was caused by broken glass. Incised wounds accounted for only 4.6%. Associated injuries were of three kinds: the companion nerve was frequently involved, a major tendon injury was present in about half the cases, and fractures were rare. Sepsis was negligible.

In distal injuries—that is, at the level of the wrist—two out of three sutures of the median nerve were followed by useful motor recovery and four out of five made a good sensory recovery. The results of ulnar nerve suture at the wrist were slightly better; four out of five led to useful sensory and motor recovery and in one case out of three some degree of independent lateral movement of the fingers was regained. There were comparatively few injuries in the forearm and at the elbow, but the results were little inferior. As might be expected, these results were better than those seen in the war series.

Several factors affecting the prognosis were examined. In children recovery was rather better than in adults; all the 22 children up to the age of 10 made an adequate sensory recovery, and in only one was there poor motor recovery. The extent of the gap to be closed by suture was a much smaller problem than in war injuries, and in only 21 was it necessary to employ an autogenous graft for repair of the nerve. Generous mobilization was employed to permit easy apposition of the nerve stumps after resection, but there was a little evidence that very extensive mobilization affected the prognosis adversely. No apparent harm resulted from a delay of six months between the injury and nerve suture, and a delay of rather over six months was still compatible with recovery.

However, the reason for this may be that almost all the lesions were distal and the distance to be covered by the outgrowing axons was therefore not great. Secondary suture should be undertaken as soon as the primary wound has healed and the tissues are free from induration. Primary suture proved an unreliable operation, although some good results were seen. There are important technical reasons why secondary suture is more satisfactory. If, as is often the case, there has been intraneural damage it is much easier to recognize it some weeks after the injury than at the time, because it reveals itself as a palpable and, on section, visible zone of intraneural fibrosis. The resection can be planned accordingly. Furthermore, the epineurium becomes thickened after the injury, and after a few weeks is an ideal structure for holding fine sutures. Most of the repairs reported were secondary.

Where there is associated damage to tendons it is best to repair them at the time of injury and simply to approximate the severed nerves. When mobilization of the digits is well advanced secondary suture of the nerves is performed without disturbance of the tendons, which, at the wrist, lie on a deeper plane, and continued movement of the fingers has no adverse effect on the nerve suture.

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ASPIRIN AND DIABETES MELLITUS

BY

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Rheumatic fever and diabetes mellitus rarely coexist (Joslin *et al.*, 1952). An opportunity to investigate this unusual combination of disease was provided by a young male diabetic (Case 1), known to take insulin, who was receiving full salicylate treatment for acute rheumatism when admitted to hospital. At the outset we were confronted with a problem, for his urine was sugar-free and the fasting blood-sugar level was normal, though he was receiving only aspirin. The possibilities first entertained were that the previous diagnosis of diabetes was inaccurate or that spontaneous remission of the disease had occurred: neither seemed likely, and the diagnostic dilemma was resolved by the reappearance of sugar in the urine one week after discharge from hospital, when aspirin had been discontinued. On re-examination at this time he was found to have glycosuria, a high fasting blood sugar, and a diabetic glucose-tolerance curve (Fig. 1).

These findings imply that rheumatic fever and diabetes mellitus are in some way incompatible, or that aspirin, the drug used in treatment of acute rheumatism, is anti-diabetic. Earlier reports indicate that salicylate was in fact used in the treatment of diabetes and that it prevented glycosuria (Gross and Greenberg, 1948). This information, together with the striking findings in our patient, led us to reinvestigate the effect of aspirin in diabetes mellitus, beginning with mild forms of the disease and, if necessary, progressing to severer types.

FIG. 1.—Results of oral glucose-tolerance tests in a diabetic patient (Case 1) while he was receiving aspirin treatment for acute rheumatism, and after the drug had been discontinued. During aspirin therapy the curve was almost normal; after stopping the drug it was diabetic.

Clinical Particulars and Methods

The effect of aspirin in another seven diabetics has been investigated. Four belonged to the overweight mild type; the other three were lean, more severe diabetics. Each patient was given a constant low-carbohydrate diet throughout the whole investigation, and this was given for about two weeks before aspirin administration to establish the effect of diet alone. Further particulars of the patients and the diets are given in Table I.

TABLE I.—Clinical Particulars of Patients

Case	Sex	Age in Years	Weight (Kg.)	Duration of Disease (Months)	Standard Diet	
					Carbohydrate (g.)	Calories
1*	M	26	56.3	24	124	1,600
2	M	58	76.0	8	150	1,950
3	F	55	82.6	48	150	1,950
4	F	52	76.8	60	130	1,700
5	F	65	69.5	48	104	1,350
6	F	58	54.9	5	104	1,350
7	F	53	56.2	4	170	2,200
8	F	15	44.5	1	130	1,700

* Patient with diabetes mellitus and acute rheumatism.

Aspirin Dosage.—An intensive course of aspirin controlled by serum salicylate estimations (Trinder, 1954) was given to each patient for 10 to 14 days. Doses of 1 to 1.6 g. were taken four-hourly, omitting one dose in the middle of the night, to maintain as high a serum salicylate level as possible without inducing serious undesirable symptoms. The effect of this intensive course of aspirin on the clinical manifestations of diabetes as well as on the principal biochemical features of the disease has been investigated. Blood sugar was estimated by Lehmann and Silk's (1952) modification of Folin and Wu's method, glycosuria by Benedict's (1911) method, and ketonuria by the method of Greenberg and Lester (1944). Oral glucose-tolerance tests were also carried out; in addition, basal metabolic rates (B.M.R.) of four patients, calculated by the method of Robertson and Reid (1952), were determined before, during, and after aspirin therapy in view of the recent establishment of the drug as a peripheral-acting metabolic stimulant (Sproull, 1954).

Fasting Blood Sugar

Table II shows the fasting blood sugars of all the seven patients at intervals throughout the investigation. The results during the week preceding aspirin administration indicate a comparatively stable pre-treatment state in all patients and