PERIPHERAL NERVE SURGERY
THE TWO-STAGE OPERATION*

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From time to time, defects in major peripheral nerves are encountered that cannot be overcome by any combination of procedures usually employed for primary suture. This is especially true during time of war when large numbers of nerve injuries are concentrated in neurological centers. When primary repair is impossible, the problem becomes one in which either a two-stage lengthening operation (bulb suture or "stretching" procedure) or a nerve graft must be employed. With the exception of those of Professor Seddon and his associates, nerve grafts have not been successful in a significant number of reported cases. If the defect cannot be made up by either a two-stage operation or a nerve graft, the only remaining possibility for improvement in function of the disabled extremity is an orthopedic operation, a tendon transfer or arthrodesis, either of which is inferior to even mediocre neurologic recovery following nerve repair.

In a series of 1713 peripheral nerve operations performed at one neurological center during World War II, we had no successful experience with nerve grafts. We encountered 92 (5.3 per cent) patients in whom repair was attempted and 77 (4.5 per cent) patients in whom the defect was overcome by the use of a two-stage operation. There were 30 patients requiring a two-stage operation upon whom we obtained follow-up data from 6 to 26 months. There were 52 (3 per cent) patients in whom the nerve injury proved to be irreparable, either before or after an attempted two-stage operation, 15 of them following an attempted two-stage repair.

In a previous publication, we catalogued our experience in overcoming large defects by primary suture and described the method that we employ in accomplishing a primary nerve repair. The essentials of the procedure to overcome such defects consist of wide mobilization of the proximal and distal segments and the use of prolonged fixation of the joints in a position to lessen the nerve defect. The surgeon must be ever cognizant of the fact that every effort should be made at the original operation to do a primary suture without resorting to the two-stage procedure, because the results are never as good in comparable cases when the two-stage procedure is used in contrast

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to a one-stage repair. The tension that is employed in the so-called “stretching operation” unquestionably produces further intraneural damage through scarring and thereby lessens the final recovery of both sensory and motor function. Nevertheless, by whatever means a nerve suture is accomplished, if there is functional recovery, the final result is considered superior to an orthopedic procedure to overcome the loss of function from the paralyzed nerve.

The two-stage operation (bulb suture or “stretching operation”) has been employed often in the repair of large defects and the gain in length resulting from it has been attributed to an actual stretching of the nerve. We doubt that it is possible to stretch a major nerve to any significant degree—certainly not over 1 cm. or at the most 2 cm. Our feeling is that the apparent gain in length following traction is ascribable to gradual shortening of the normal course of the nerve. Properly performed traction may provide an additional 5 or 6 cm. in length, but at the same time causes additional injury throughout the entire length of nerve subjected to it. Thirty to 40 per cent of function is lost as a direct result of this traction in contrast to what one might expect had the nerve ends been united without tension and by the use of other procedures to shorten its course. It is for this reason that we consider the two-stage operation a last resort for nerve repair, and preferable only to a nerve graft.

In the literature on peripheral nerve surgery, little attention has been directed toward the method of performing the two-stage operation. It is our belief that damage to the nerve can be reduced to a minimum by observation of certain technicalities which we have employed. Usually, the suture is performed with little regard for the additional amount of injury that results from uniting the proximal and distal lesions to each other with catgut, heavy silk, or wire sutures. Others have sutured the neuromas to fascia, muscle, or periosteum, markedly flexed the joints, and later employed rapid extension within 10 to 14 days during which time the nerve presumably is being “stretched.” Actually the nerve is being forcibly pulled from its normally somewhat tortuous course in the extremity. We are certain that this method produces such extensive injury within the nerve, both in the proximal and distal segments, that the already large defect may be actually increased rather than decreased, making eventual repair impossible. When this rapid method of traction and extension is employed, one will find as thin slices of the segments are made in search of an anatomical design somewhat like normal nerve, that progress may extend many centimeters into the proximal or distal ends before anything resembling normal architecture is encountered. The homogeneous mass of fibrosed and degenerated nerve that has destroyed the normal architecture represents damage from the rapid traction applied to the nerve under tension.

After observing several patients with extensive defects from their original wound in whom bulb suture had been done previously, we abandoned the usual technique in favor of one using the same care as that used in a patient undergoing primary repair. Even with this superior method, some
injury to the nerve from traction always occurs near the suture site and as far as 1 or 2 cm. both in the proximal and distal segments, thereby sacrificing a considerable amount in final result. For this reason, we strongly advocate extensive mobilization and the use of every reasonable maneuver to obtain a primary one-stage repair, reserving the two-stage procedure only as a last resort.

METHOD

We believe the following method the least injurious to the nerve, and, if carefully performed, it minimizes fibrosis in the segments adjacent to the proximal neuroma and distal glioma thereby affording a chance of performing definitive suture of reasonably normal nerve ends.

First Stage. As shown in Fig. 1, the nerve both proximal and distal to the lesion is first mobilized through a long incision (a) which will overcome a great deal of the

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**Fig. 1.** (a) Outline of skin incision. (b) Lesion exposed and nerve segments mobilized. (c) Line of partial resection of neuromas. (d) Suture of partially removed neuromas. (e) Tantalum foil cuff in place.
apparent defect. This is followed by freeing the severed ends and estimating the size of the defect (b). If it is obvious that the ends cannot be approximated when the neuromas are resected, the proximal and distal segments are mobilized as completely as possible and the two neuromas brought as near together as possible. The defect is further reduced by placing the limb in the position designed to lessen the gap in the nerve. Next, the length of the proximal and distal neuromas is measured to determine what portion can be resected and still accomplish approximation of the ends of the partially removed lesions (c). When this resectable length is determined, excision of this amount of the proximal neuroma and distal glioma is made (d) so that end-to-end suture can be accomplished even if the suture site is under slight tension. In other words, the same method is used for suture of the partially removed lesions as is used in primary suture. For this we use .003 or .005 tantalum wire swedged on a cutting needle and we never employ a sling or retention suture of any sort. The suture site is then wrapped in a cuff of tantalum foil, 3 to 5 cm. long, which is held in place by loosely tied ligatures of plain catgut (e). This is the one instance in which we feel that tantalum foil has a place in peripheral nerve surgery. The wound is closed in the usual fashion and the limb is completely encased in a plaster cast rather than any type of splint or mold.

The cast is left in place 4 to 6 weeks in much the same manner as is done in primary nerve suture, when the defect has been repaired satisfactorily in the original procedure. When the cast is removed, the limb is slowly extended over an additional period of 3 to 4 weeks and under no circumstance is rapid extension permitted. Fortunately, when an extremity is maintained in a cast for this period of time, rapid extension is partially prohibited by moderate fibrosis that occurs in the incorporated joints, and, in addition, the patient is warned against rapid extension of these joints. The 6- to 9-week period between operative procedures will have no appreciable bearing on the final neurologic result.

Second Stage. When full extension of the limb has been accomplished, the second-stage procedure is begun (Fig. 2) by exposing the nerve through the original incision (a) and removing the tantalum foil cuff. During this period, the cuff will lessen the amount of fibrosis that might occur between the suture site in the nerve and the surrounding scar tissue. A thin layer of mesothelial tissue surrounds the nerve in the region where the foil has been applied and a similar layer forms between the foil and the tissues in the nerve bed. The site of suture and the nerve proximally and distally are palpated to estimate the amount of scarring that has resulted from the traction. Investigation by palpation affords a very excellent estimate of the point where the devastating type of scarring is present. This portion of the nerve will feel firm and cord-like, whereas that portion of the nerve where the elements approach normal is soft and pliable. The joints of the extremity are then flexed to be certain that the nerve ends can be approximated when the extensively scarred segment has been resected. Ideally, one would want to resect all of the portion that feels firm and obviously scarred, but it is just as obvious that one cannot excise all of this portion of the nerve if it makes approximation of the ends impossible. Occasionally in such case, one may have to be satisfied in performing a repair involving a portion of nerve that is somewhat distorted by scar tissue. The resection of the involved portion is continued by serially excising small segments in an effort to demonstrate grossly normal-appearing nerve structure. The majority of the resection will be made in the proximal segment. Completely normal nerve as seen on cross section will never be encountered (b and c). When the best possible cross section of nerve is obtained in which suture can be accomplished without undue tension, the nerve ends are approximated using
a .003 tantalum wire without a retension or sling suture and without the use of a tantalum cuff (d). The limb is again encased in a circular plaster cast which is maintained for 4 to 6 weeks following which full extension of the limb is gradually allowed over a period of an additional 2 to 4 weeks. When this point has been

**Fig. 3.** Median nerve suture, second stage, proximal ¼ of arm. (Right) Proximal cross section showing abnormal, large nerve fibers and fibrosis. (Left) Distal cross section showing degeneration and glistening, homogeneous surface.

First-stage defect 8.0 cm.; second-stage defect 6.0 cm.

Result in 11 months was 60 per cent (fair) with return of crude sensation and sweating and 50 per cent motor power in pronator teres, flexor digitorum sublimis and flexor digitorum profundus. (Mag. X3)
reached, the position of the wires at the suture site is checked by x-ray. If there is separation of the wire sutures, the suture line has not held and must be redone.

We wish to point out again that we have seen recovery occur following the above-described procedure even though the nerve ends that were sutured appeared grossly nothing more than a homogeneous mass replacing the normal anatomy that one sees in the usual nerve repair (Fig. 3). Admittedly, the final neurologic recovery is small in such case, but it is preferable to complete loss of nerve function. Any return of sensation in an anesthetic area is useful and any motor recovery is preferable to complete loss of nerve function in that muscle. When functional recovery is inadequate,

Table 1 shows data on 92 attempted two-stage operations. Of these, 77 were completed and in 15 instances the defects were irreparable. Unfortunately, the follow-up period of 45 patients was inadequate because of their separation from Army service too soon following their second-stage operation. In 30 cases the follow-up observation varied from 6 to 26 months, averaging 11.3 months. Only 2 complete failures occurred following successful two-stage repair: 1 radial and 1 ulnar nerve. Our average result was only fair (55.6 per cent) compared to results of 80–85 per cent obtained in a simi-
lar but larger group of primary nerve repairs. Of the 30 patients with adequate follow-up, 17 showed results up to 60 per cent and only 13 better than 60 per cent, with only one ulnar nerve yielding a result as high as 80 per cent. These data bear out the previous statement, that when a two-stage operation is required, one is penalized in the order of 30 to 40 per cent possible recovery of function.

CONCLUSIONS

1. A method of performing a two-stage operation in cases of extensive peripheral nerve defects which will result in minimal traction injury to the adjacent and normal nerve substance is described and illustrated.

2. The two-stage operation is a last-resort procedure and should be used only in preference to a nerve graft when it has become obvious that primary suture cannot be employed. We believe this procedure is preferable to nerve grafting.

3. Results obtained by this method are compared with those of primary suture.

REFERENCES

