Anatomical Basis for Repair of Ulnar and Median Nerves in the Distal Part of the Forearm by Group Fascicular Suture and Nerve-Grafting

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ABSTRACT: The topography of the intraneural fascicular groups must be understood if the treatment of acute lacerations of the major nerves in the forearm is to be successful. Most lacerations in the upper extremity occur at the wrist and in the distal half of the forearm. With microsurgical longitudinal dissections and serial sections, we studied the intraneural topography of the fascicular groups of the median and ulnar nerves utilizing forty-five fresh frozen or refrigerated specimens. We devised a new technique of light photography to demonstrate the distinct boundaries of the fascicular groups. The intraneural fascicular groups provide the anatomical basis for the recommended surgical techniques of group fascicular repair and nerve-grafting.

In 1945, Sunderland reported his classic study, “The Intraneural Topography of the Radial, Median and Ulnar Nerves”, and in 1968 his book Nerves and Nerve Injuries was published. Since then, his description of the intraneural fascicular pattern has been widely quoted and has been confirmed by the studies of Jabaley et al. and Williams.

For our purposes, two points may be drawn from Sunderland’s reports.

1. The funicular pattern in both the ulnar and median nerves is continually modified along the length of each nerve by repeated divisions, anastomoses, and changes in the relative positions of the funiculi. The changes in position of individual funiculi may take place within a short expanse of the nerve, often in a segment of 2.5 millimeters or less.

2. The funiculi (also called fascicles or bundles) arrange themselves in definite groups that are usually identifiable along the course of the nerve for distances of several centimeters, especially in the distal portions of the two nerves. Sunderland reported that the bundles in the branches of each nerve course as separate and distinct groups within the nerve, and despite the changing patterns of the individual funiculi in cross section, the bundle groups, during their course in the nerve, are individually identifiable for variable, and often considerable, distances above the site of branching.

Many clinicians have cited our first point to support claims that a precise anatomical realignment of fascicles in the repair of lacerated peripheral nerves is impossible. Our second point generally has been overlooked, as it relates to surgical treatment.

The present study was prompted by clinical observations by the principal one of us (J. A. C.) made at the Cook County Hospital between July 1978 and June 1979. Of fifty-six cases of laceration of the major peripheral nerves of the upper extremity, forty-one were lacerations of the median or ulnar nerve, or both, at the wrist or in the distal half of the forearm.

These observations emphasized the significance of intraneural fascicular group topography in the treatment of acute lacerations of the major nerves at the wrist and distal half of the forearm. Also, the fascicular group arrangement is more constant distally in the major nerves of the upper and lower extremities.

We decided to attempt to reconfirm Sunderland’s observations on the intraneural topography of the median and ulnar nerves, with special attention to the fascicular groups, and to amplify his studies. Our purpose was to investigate the anatomical feasibility of suturing the groups of fascicles individually.

Materials and Methods

We used forty-five fresh refrigerated or fresh frozen specimens of the upper extremity, and in seventeen specimens we did a microsurgical longitudinal dissection of the fascicular groups of the median and ulnar nerves. We traced the terminal branches of the two nerves from the palm in the proximal direction, and we also traced the dorsal cutaneous branch of the median nerve and the palmar cutaneous branch of the ulnar nerve. The muscular cutaneous branches
Fig. 1-A

Figs. 1-A through 1-D: Histological sections of the left ulnar nerve, one centimeter apart (hematoxylin and eosin, × 10).
Fig. 1-A: At a level fifteen millimeters proximal to the radial styloid process.

of the median and ulnar nerves in the proximal part of the forearm were followed in the proximal direction, utilizing a similar microsurgical dissection technique. In ten specimens we made a series of sections at five-millimeter intervals and studied them by a method similar to that described by Sunderland. We used hematoxylin and eosin and Mason trichrome stains. Special attention was directed to the group fascicular patterns of the median and ulnar nerves...
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(Figs. 1-A through 1-D and 5). This emphasis was different from those of previously published anatomical studies, which focused their attention on the individual fascicles of the nerves.

We also devised a new photographic technique to study a series of consecutive segments of the median and ulnar nerves in sixteen specimens (Figs. 2-A and 2-B). The fascicular group topography of the median and ulnar nerves was studied in two specimens utilizing a series of sections, from the edge of the palm to the proximal part of the arm, by scanning electron microscopy. The technique was described by Van Beek et al. in 1979 (Fig. 3).

In addition to the data obtained from these forty-five fresh specimens, additional information was obtained from dissection of sixty-six formalin-fixed specimens from cadavers to determine the locations and courses of the motor fascicular groups of the ulnar nerve at the wrist and in the distal part of the forearm.

Results

Ulnar Nerve

The ulnar nerve gives rise to three terminal branches
Figs. 2-A and 2-B: Conventional photographs of cross-sectional surfaces of segments of the left ulnar nerve made with a camera that had a bellows attachment (× 5). Fig. 2-A: Fifty millimeters proximal to the radial styloid process.

at the level of the proximal edge of the palm — one muscular and two cutaneous (Fig. 4). The first is a branch that supplies the hypothenar muscles and interosseous muscles. One cutaneous branch proceeds to the fourth web space as the common digital nerve, while the other supplies the hypothenar skin and the ulnar side of the little finger. These three branches can be followed proximally as three distinct fascicular groups for fifty millimeters from the radial styloid process (Figs. 1-A through 1-D). The two sensory groups merge at that level. From the fifty-millimeter to the ninety-
millimeter level, the merged sensory and the motor fascicles can be identified as two distinct fascicular groups separated by a firm condensation of connective tissues (the intraneural epineurium) (Figs. 2-A and 2-B). At the ninety-millimeter level, these two groups merge. The motor fascicular group may therefore be identified as a distinct entity from the tip of the radial styloid process to a point ninety millimeters proximal to the palm. In all but two of the 111 specimens that were studied, the motor fascicular group of the ulnar nerve at the distal part of the forearm was located at the ulnar-dorsal position or central dorsal position. In the exceptional two specimens, it was located at the radial-dorsal
Histological section of the right median nerve at a level twenty millimeters proximal to the radial styloid process. A indicates the radially located combined motor and sensory group. The motor fascicles to the thenar muscles are on the volar aspect of this group. B and C are the sensory fascicular groups from the common digital nerves of the second and third web spaces, respectively (hematoxylin and eosin, × 10).

At the level of the distal third of the forearm, the motor fascicular group constituted 30 to 35 per cent of the total fascicular cross-sectional area of the ulnar nerve. The dorsal cutaneous branch is separate from the main trunk of the ulnar nerve at, and distal to, the junction of the middle and distal thirds of the forearm (eighty to ninety millimeters from the palm). It was followed proximally as a separate fascicular group, running side by side with the combined fascicular group from the three terminal branches, from the ninety-millimeter level to the 250-millimeter level proximal to the palm (Fig. 3).

In the proximal half of the forearm, the fascicular groups that correspond to the three terminal branches at the proximal edge of the palm become distinct. However, at the elbow, the specific fascicular groups that form the motor branches to the flexor carpi ulnaris and the ulnar half of the flexor digitorum profundus can be readily identified. They remain as distinct entities for approximately ten centimeters proximal to the elbow.

Median Nerve

At the level of the wrist and in the distal quarter of the forearm, three fascicular groups may be identified in the median nerve, and they can be traced as separate entities for five to seven centimeters proximal to the proximal edge of the palm. At the ulnar side, there are two sensory fascicular groups (Fig. 5), which form the two common digital nerves to the third and second web spaces. On the radial side, there is one large fascicular group consisting of sensory and motor fascicles—the sensory fascicles continue distally as the radial digital nerve of the index finger and the two digital nerves of the thumb, and the motor fascicles to the thenar muscles are located on the volar aspect of the mixed sensory-motor fascicular group. Thus, in relation to the rest of the median nerve, the motor fascicles to the thenar muscles are in the volar-radial position.

The motor fascicles to the two radial lumbrical muscles are also located in the mixed sensory-motor fascicular group, situated ulnar to the motor fascicular group to the thenar muscles. More distally, in the palm, the motor branch to the index lumbral muscle accompanies the radial digital nerve of the index finger. The motor branch to the lumbral muscle of the long finger accompanies the common digital nerve to the second web space. The motor fascicles of the median nerve at the distal end of the forearm constitute only 10 per cent of the total fascicular cross-sectional area of the nerve.

The palmar cutaneous branch is separate from the main part of the median nerve at approximately seventy millimeters proximal to the radial styloid process, and its sensory fascicular group can be traced proximally as an entity to the 150-millimeter level; that is, to the middle third of the forearm.

In the proximal half of the forearm, the fascicular groups that correspond to the terminal branches become indistinct, but the motor fascicular groups that terminate as branches to the muscles of the forearm may be traced for about ten centimeters proximally from the site of branching.

Discussion

Because the major nerves at the distal part of the forearm are lacerated so frequently, a study of the topography of the intraneural fascicular groups at these levels has special clinical significance.

Our findings are based on studies of forty-five fresh specimens, a larger number than were studied by others previously, and they confirm that the fascicular group associated with the median and ulnar nerves has consistent anatomical features in the distal portion of the forearm. We introduced a new photographic technique for portrayal of
the distinct entities of the fascicular groups at serial levels (Figs. 2-A and 2-B).

The surgical relevance of our findings should be emphasized because they provide an anatomical basis for group fascicular repair. In 1917, Langley and Hashimoto, of Cambridge University, suggested the idea of separate suture of fascicular groups, and advised cutting open the inner, dense epineurial sheath (intraneural epineurium). The technique of group fascicular repair has been described by Van Beek and Kleinert as well as by Sunderland (Fig. 6). Utilizing the operating microscope, one may readily identify, match, align, and repair the fascicular groups.

Group fascicular repair may be conceptualized as inner

segment of nerve is lost, the fascicles at the two nerve ends will not correspond, so that fascicle-to-fascicle repair by perineurally placed sutures is precluded. Under such conditions, one should be able to identify corresponding fascicular groups rather than individual fascicles at the nerve ends, and then microsurgical group fascicular repair will be possible because the fascicular groups remain as identifiable entities for several centimeters proximal to the wrist.

In the surgical treatment of acute lacerations of the major peripheral nerves, we advocate microsurgical group fascicular repair or microsurgical epineurial repair with correct alignment of the fascicular groups. We do not advocate fascicular (perineural) repair.

The fascicular group arrangement of major peripheral nerves is also important for the technique of interfascicular nerve-grafting as described by Millesi and Millesi et al. They pointed out that, using the operating microscope, nerve grafts can be utilized to bridge the gap between the corresponding fascicular groups (Fig. 7).

We believe that the relatively constant location of the motor fascicular group of the ulnar nerve at the distal part of the forearm is particularly important. In all but two of the 111 specimens that we studied, that fascicular group was located at the ulnar-distal or central dorsal position in the nerve. To enhance the chance of reinnervation of the intrinsic muscles of the hand, one should make a special

epineurial repair. The epineurium may be divided into external epineurium and intraneural epineurium. The external epineurium surrounds the entire nerve, while the intraneural epineurium separates and surrounds individual fascicular groups or individual fascicles (Figs. 1-B and 2-B). The epineurium, either external or intraneural, lends itself to separate suturing without injury to the encased fascicular groups. Utilizing the operating microscope, sutures may be carefully applied on the outer or inner epineurium between the fascicular groups, without direct injury to the fascicles.

Group fascicular repair is preferable to fascicular (perineural) repair because it requires less dissection and causes less surgical trauma and resultant scarring. If a significant

Fig. 6

Group fascicular repair.

Fig. 7

Group fascicular nerve-grafting.
effort during nerve suture to correctly identify and align this motor fascicular group.

We recognize the value of the early work of Sunderland and the later contributions of Jabaley et al. and Williams, and most of the points that they made have been confirmed in our study. Our dissections constitute a larger number of specimens than do the previously published reports, and we further highlight the privileged anatomical fact of the more constant fascicular group arrangement in the intraneural topography of the ulnar and median nerves at the distal part of the forearm, where the majority of acute lacerations occur clinically.

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References