# Intraneural Topography of the Ulnar Nerve in the Cubital Tunnel Facilitates Anterior Transposition

Greg P. Watchmaker, MD, Gilbert Lee, MD, Susan E. Mackinnon, MD,
St. Louis, MO

The surgical management of cubital tunnel syndrome includes anterior transposition of the ulnar nerve. The success of all transposition procedures is dependent on placement of the nerve anterior to the medial epicondyle without tension. Fifteen cadaveric upper extremities underwent anterior transposition followed by anterior transposition with separation of the most proximal motor branches from the main ulnar nerve for a distance of 1, 2, and 3 cm. Proximal dissection of these motor branches achieved an average gain in distance from the epicondyle of 71%, with an average distance from the epicondyle of 3.6 cm. The intraneural topography of the ulnar nerve was studied in five additional cases. Cross-section analysis of the fascicular anatomy at 333 μm intervals along the length of the nerve with longitudinal reconstructions confirmed a safe dissection plane without interfascicular plexus formation. The most proximal motor branch in the forearm could be traced proximally an average of 6.7. cm within the nerve before interfascicular mingling occurred (range 6.0 to 7.5 cm). Thus, 6.0 cm represented the upper limit of safe proximal dissection in these nerves. Proximal separation may be performed without disruption of interfascicular plexus connections and will facilitate anterior transposition. (J Hand Surg 1994; 19A:915–922.)

Many surgical techniques have been described for the management of cubital tunnel syndrome. Successful treatment by transposition requires not only a complete release at all points of compression, but also prevention of recurrent compression in its new transposed position. Leaving the transposed nerve in close proximity to the medial epicondyle subjects the nerve to injury from direct trauma as well as traction injury if it becomes tethered to adjacent bone or fibrous tissue. Posterior motor branches tend to tether or pull the nerve posteriorly and limit transposition.

This study was designed to answer whether separation of these motor branches is topographically feasible, and if so to what extent this maneuver would facilitate anterior transposition of the ulnar nerve.

## Materials and Methods

### Transposition Measurements

Transposition distances were evaluated in 15 ulnar nerves. Fifteen nonfixed cadaveric upper extremities disarticulated at the shoulder were obtained for analysis. With the elbow in 30° flexion, standard skin incisions were used to expose the ulnar nerve for anterior transposition procedures. The nerve was exposed from 5 cm proximal to the level of the medial epicondyle to 5 cm distal to the medial epicondyle. A 5-0 silk suture placed on the nerve at the level of the medial epicondyle was designated the 0 cm mark. Points distal to this suture were given positive values; points proximal were

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From Washington University Medical Center and Barnes Hospital, St. Louis, MO.

Received for publication Aug. 13, 1993; accepted in revised form Oct. 29, 1993.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

Reprint requests: Susan Mackinnon, Division of Plastic Surgery, Washington University School of Medicine, One Barnes Hospital, Suite 17424, St. Louis, MO 63110.

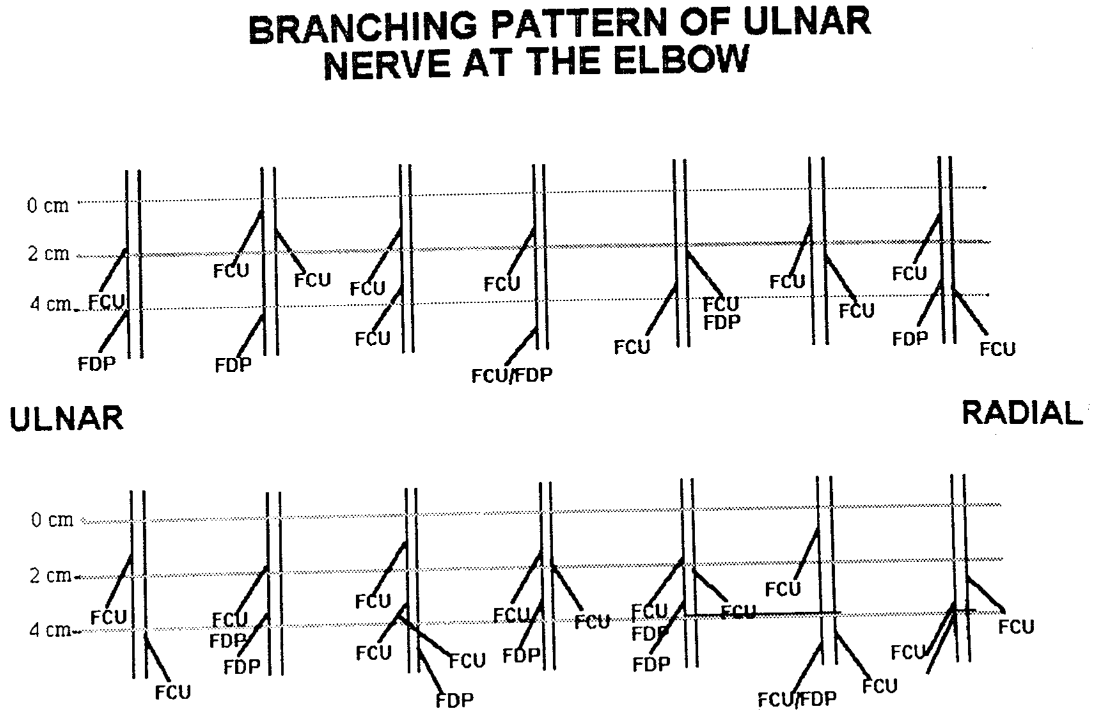

**Figure 1.** The branching pattern for each ulnar nerve is demonstrated. The medial epicondyle is designated 0 cm. Variability in number and level of branching between specimens is present.

given negative values. Sutures were then placed at measured intervals proximally and distally.

A reference suture was also placed on the medial epicondyle. Branches to the flexor carpi ulnaris (FCU) and flexor digitorum profundus (FDP) were identified as to their number and distance distal to the epicondyle (Fig. 1). The nerve was then released from its bed and transposed anteriorly. A small articular branch was found in two specimens. This branch was sacrificed. The distance was then recorded from the nerve's original untransposed bed to its new position. This transposition distance was recorded at the level of the medial epicondyle and also at 1, 2, 3, and 4 cm proximal and distal to the epicondyle. Distances were also measured from the epicondyle to the transposed nerve.

After these measurements were recorded, a careful separation of the proximal motor branches from the main ulnar nerve was performed. The most proximal motor branch in the forearm was always the branch that tethered the ulnar nerve to the epicondyle. Using microsurgical instruments, this branch was separated under 2.5 × loupe magnification from the other ulnar nerve fascicles for a distance of 1 cm. The plane of dissection was the epineurium between the main ulnar nerve and the motor branches. If two branches exited the nerve at the same level, both branches were dissected free as a group. Following this maneuver, the nerve was then transposed again and measurements were taken. This process was repeated again after 2 and 3 cm of dissection. After each centimeter of separation, the gain in transposition was recorded. A total of 72 measurements were thus taken on each nerve. Once all measurements were completed, each motor branch was traced distally to confirm which muscle or muscles it innervated.

A frequent observation was a motor branch arising from the medial aspect of the nerve that then crossed anteriorly and laterally to innervate the FCU (Fig. 2A). On occasion, this branch was found arising with a branch traveling medially, also innervating the FCU (Fig. 2B). When this anatomy was present, adequate transposition could only be obtained by separating these two branches from each other (Fig. 2C).

## Topographic Analysis

Cross-sectional topographic study was performed on five ulnar nerves in the region of the elbow. Five nonfixed cadaveric upper extremities were obtained for dissection. The ulnar nerve and its branches were dissected along a distance from 8 cm proximal to the medial epicondyle to 8 cm distal with the aide of loupe magnification. The level at which each branch left the ulnar nerve was measured in millimeters. The medial epicondyle was designated 0 mm.

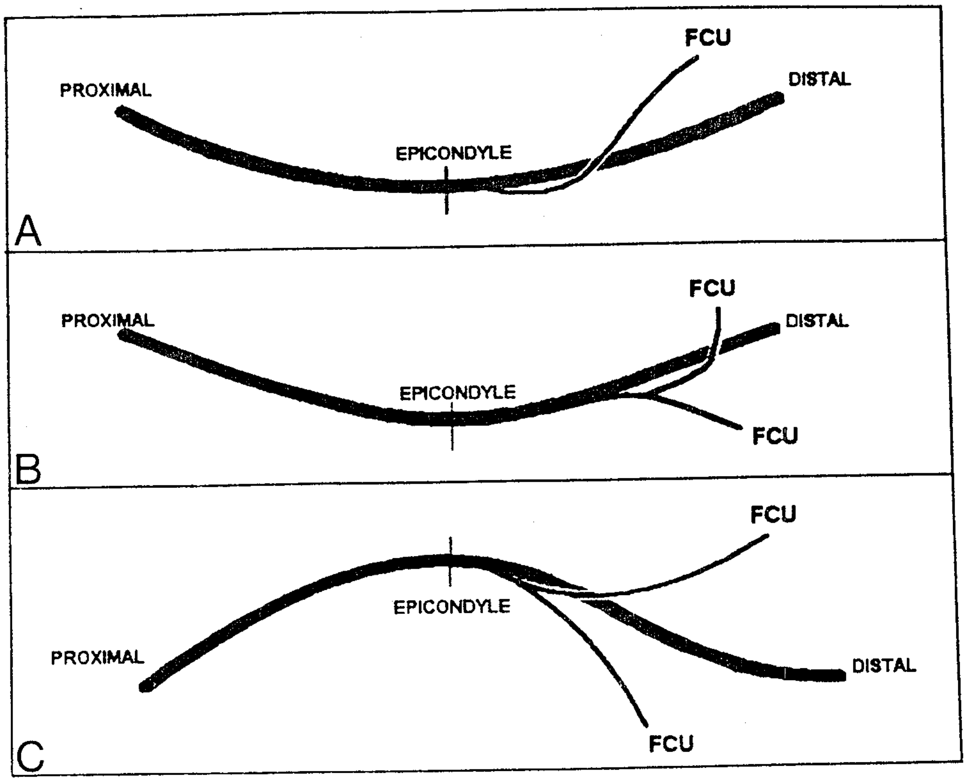

**Figure 2.** (A) The ulnar nerve often contained a motor branch that crossed from medial to lateral over the nerve. (B) In several nerves, the proximal branch bifurcated to travel both medially and laterally to innervate separate fibers of the FCU. (C) Separation of these branches from one another was necessary to achieve adequate transposition.

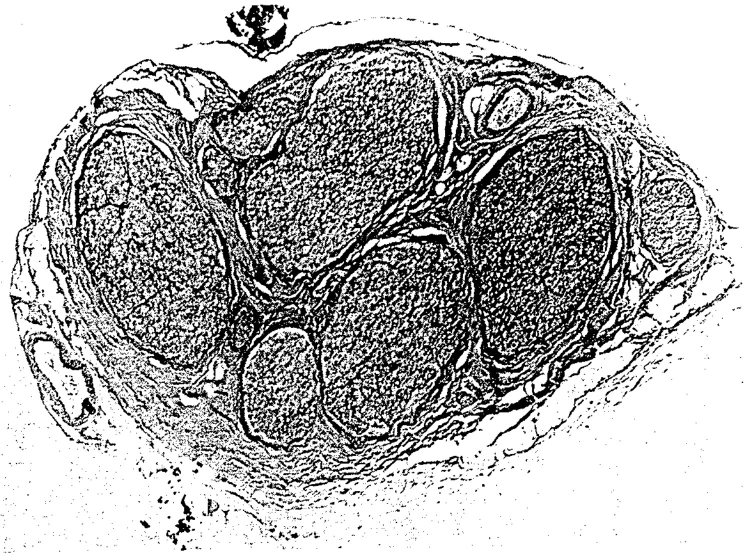

**Figure 3.** Ten-micron-thick sections were cut every 333 μm. The dark fibers of the orienting suture are visible near the top. The fascicle composing the proximal motor branch to the FCU is on the far right. A well-defined layer of epineurial tissue exists between this fascicle and the main ulnar nerve fascicles at this level.

with proximal points given negative values and distal points given positive values. 6-0 silk orientation sutures were passed along the length of nerve through the epineurium. Nerves were labeled, photographed, fixed in formalin, and processed en bloc. The nerves were then cut into 3 cm segments and embedded into paraffin cylinders for microtome sectioning.

Each block of nerve tissue was cut into sections 10 μm thick. A section of tissue was saved every 333 μm, and three such sections were mounted on a single glass slide. In this manner, a single slide represented 1 mm of nerve length. Each nerve was sectioned in this manner over its entire dissected length yielding approximately 480 sections per nerve (160 slides per nerve). The tissue was then stained with hematoxylin and eosin (Fig. 3).

The nerves thus processed were analyzed using software previously described.[1] Briefly, each section was entered into a computerized database using a microprojector and digitizing tablet. The fascicular patterns thus entered were followed proximally and distally to identify changes in orientation and fascicular branching. Each fascicle was followed in a distal to proximal direction, noting the levels at which each fascicle merged with neighboring fascicles. Using this technique, the level at which each fascicle to the FCU and FDP merged into adjacent fascicles was determined. This level was then compared with the level at which each branch grossly separated from the ulnar nerve distally as determined at the time of the dissection. The distance between these two levels represented the distance that the branch could have been safely separated from the main ulnar nerve without damaging plexus interconnections.

## Results

### Transposition Measurements

The overall branching pattern to the FCU and FDP was variable (Fig. 1). The most proximal motor branch arose an average of 1.6 cm distal to the epicondyle (range, 0.5–3.2 cm). This branch most frequently provided innervation to the FCU alone (12 specimens). The second branch arose an average of 3.4 cm distal to the epicondyle (range, 1.6–5.2 cm). Branches arising more than 5 cm distally were not identified, as the dissection was stopped at this point.

Two specimens contained a small branch exiting the ulnar nerve at the level of the epicondyle. This branch could be traced directly into the joint connective tissue. This branch did not travel to any muscle group and likely represented an articular branch. When present, this branch was sacrificed prior to transposition.

We determined the distance the nerve could be

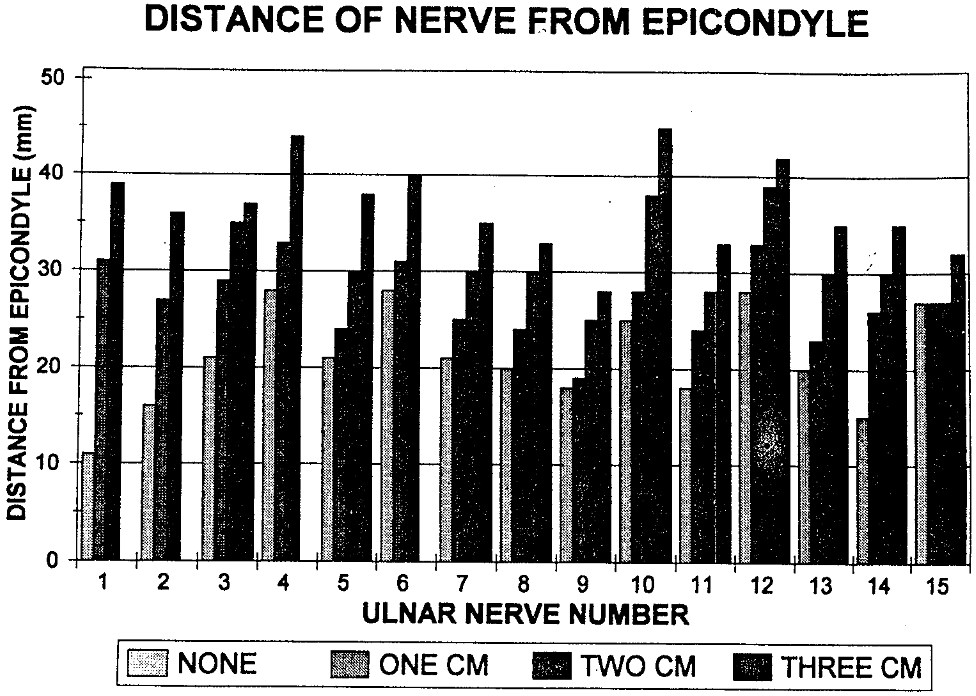

**Figure 4.** Fifteen ulnar nerves underwent anterior transposition followed by proximal dissection of the first motor branch from the main ulnar nerve. Significant gain in transposition away from the epicondyle was achieved.

transposed before and after separation of the motor branches from the main ulnar nerve. This distance was measured from the prominence of the medial epicondyle to the transposed nerve (Fig. 4). The average distance to the epicondyle was 2.3 cm (range, 1.5–3.0 cm) prior to this maneuver. There was an average gain in transposition of 25% with 1 cm dissection, 55% with 2 cm, and 71% with 3 cm dissection. Following proximal dissection, the average distance from the epicondyle was 3.6 cm (range, 2.8–4.5 cm). Measurements were taken with the nerve placed superficially on the flexor muscle mass. Gain in transposition after placement in a submuscular plane may be greater.

The gain in transposition varied with the level and pattern of branching. It also varied with the point along the nerve that was investigated. Figure 5 illustrates the increase in transposition along the length of two nerves. The greatest gains were achieved in the segment of nerve nearest the epicondyle.

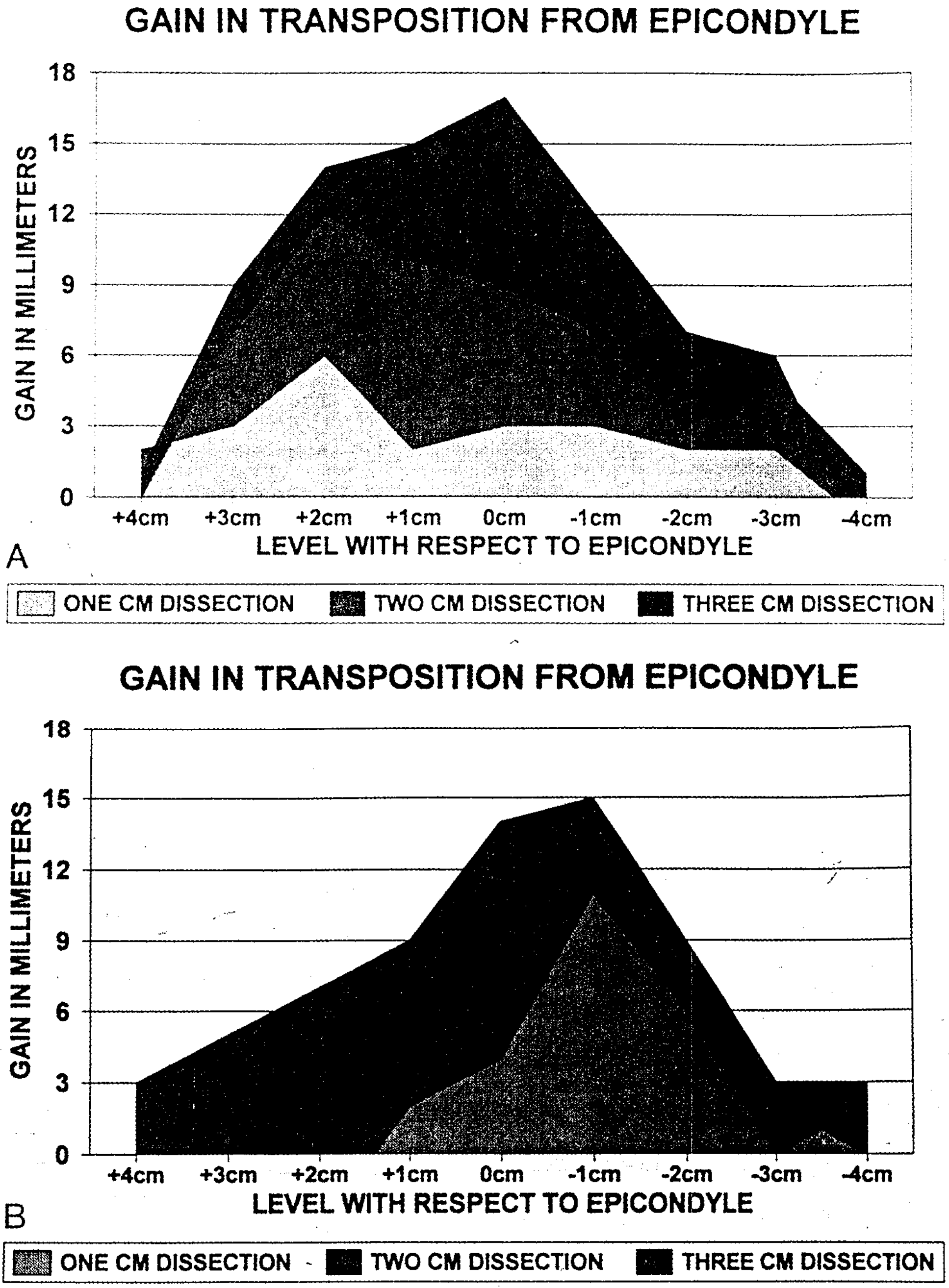

Figure 5. Proximal dissection achieved the greatest gain in transposition where the nerve was tethered near the epicondyle by motor branches in this specimen. (B) Similar pattern observed in an additional ulnar nerve.

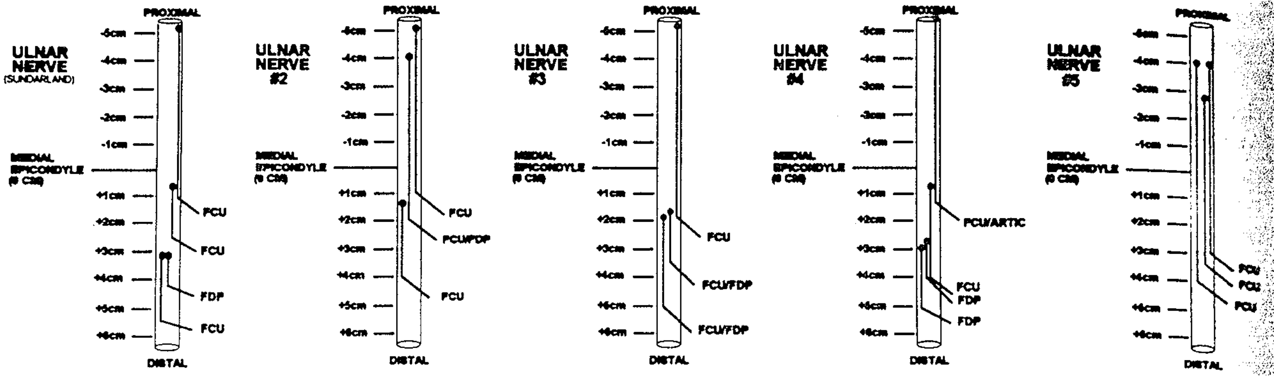

Figure 6. Motor branches are labeled distally at the level that they grossly left the main ulnar nerve. Solid circles indicate the level at which plexus interconnections occurred for these motor branches. The proximal motor branches could be traced a minimum of 6 cm prior to interfascicular connections.

## Fascicular Topography

Cross-sectional fascicular studies demonstrated that the fascicles that formed the most proximal motor branches of the ulnar nerve in the forearm ascended for long distances before intermingling with other fascicles. Fascicles from these motor branches ascended an average of 6.7 cm (range, 6.0–7.5 cm) before plexus formation and intermingling with other fascicles occurred (Fig. 6). More distal motor branches in the forearm had a more variable internal topographic pattern. The second motor branch could only be traced an average of 3.8 cm (range, 1.7 cm–6.3 cm) prior to joining other fascicles.

The number of fascicles in each nerve decreased at the level of the epicondyle. At the elbow, the ulnar nerve typically consisted of one or two large fascicles along with a separate smaller fascicle or fascicular group (Fig. 7). More distally, this smaller fascicular group gave rise to the first motor branches to the FCU and FDP.

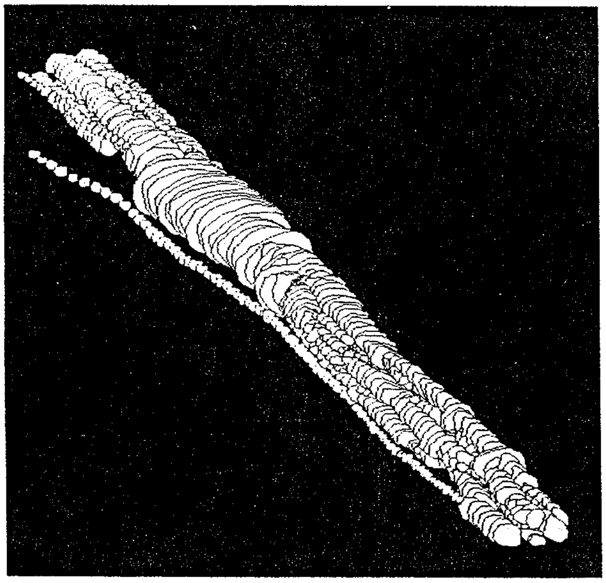

Figure 7. Longitudinal three-dimensional reconstruction of the ulnar nerve from 6 cm proximal to the epicondyle (lower right) to 4 cm distal to the epicondyle (upper left). A small motor branch can be seen entering the nerve on the left and traveling 7 cm prior to intermingling with other fascicles.

## Discussion

The reasons for sub optimal results following anterior transposition for cubital tunnel syndrome are many and include tethering by posterior motor branches. Several techniques have been proposed to deal with the branches to allow adequate transposition. In 1942, Learmonth[2] described and illustrated a technique of transposition including proximal dissection of these motor branches in the forearm as a mechanism of "freeing up" their tethering effects.[3,4] Intramuscular dissection of the motor branches has also been advocated to facilitate transposition.[5] Several authors, however, do not mention any approach to the management of these tethering branches. This leaves one to conclude that these branches are either left *in situ* to tether the nerve or are sacrificed to allow anterior transposition.[6,7] In our dissections, we found articular branches only rarely present. Thus if "small branches" are frequently sacrificed, they more likely represent proximal motor branches and not articular branches. This viewpoint is supported by the microdissection studies of Jabaley, in which no articular branches were documented in the dissection of four ulnar nerves.[8]

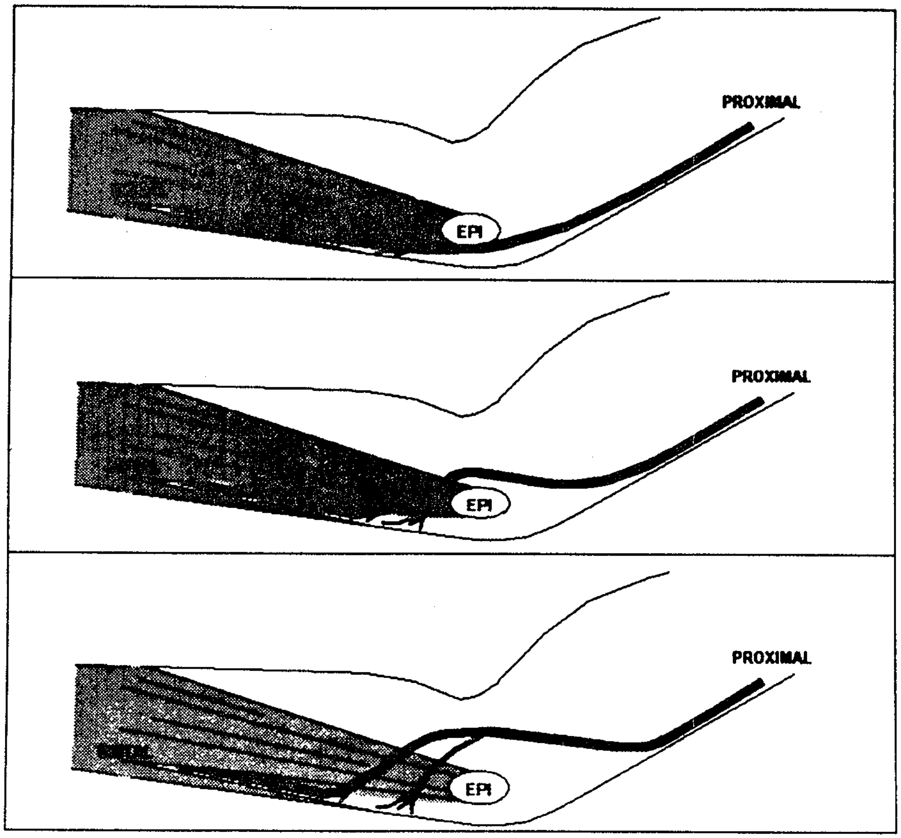

Figure 8. (A) The nerve as it courses through the cubital tunnel. (B) Anterior transposition with tethering by motor branches. The nerve remains close to the epicondyle. (C) Increased transposition after proximal dissection of the first motor branch. The nerve lies well away from the epicondyle.

Our dissections demonstrate that the ulnar nerve can be transposed further anteriorly if the proximal motor fascicles are separated from the main ulnar nerve (Fig. 8). This technique increased the distance from the medial epicondyle in all specimens. Sacrifice of motor branches to the FDP or FCU was not necessary.

Cross-sectional analysis of the course of each motor fascicle in the ulnar nerve at the elbow demonstrates that this dissection is possible without disturbing interfascicular plexus connections. A minimum of 6 cm of dissection could be safely performed on the proximal motor branch. In contrast, a conservative dissection of the more distal motor branches is warranted, since plexus interconnections occur within 1.7 cm of joining the main ulnar nerve. The topography described in this report is supported by Sunderland's dissection of a single ulnar nerve, in which a distance of 6 cm was also found before plexus connections occurred (Fig. 6).[9] Longitudinal microdissection has also previously demonstrated dissection distances of 7–10 cm.[8] In addition, examination of the deep motor branch of the ulnar nerve at the wrist has shown few interfascicular connections.[10] The safety of this procedure is supported by primate[11] and human studies.[12]

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