Double Motor Nerve Transfer for All Finger Flexion in Cervical Spinal Cord Injury: An Anatomical Study and a Clinical Report

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Purpose To explore the feasibility of restoring all finger flexion after a cervical spinal cord injury.

Methods Double nerve transfer was conducted in 22 cadaver upper extremities. Donor nerves were the brachialis branch of the musculocutaneous nerve and the extensor carpi radialis brevis (ECRB) branches of the radial nerve. Recipient nerves were the anterior interosseous nerve (AIN) and the flexor digitorum profundus (FDP) branch of ulnar nerve (ulnar-FDP). Nerve transfers were evaluated on 3 parameters: surgical feasibility, donor-to-recipient axon count ratio, and distance from the coaptation site to the muscle entry of recipient nerve. A complete C6 spinal cord injury reconstruction was accomplished in a patient using a double nerve transfer of ECRB to ulnar-FDP and brachialis to AIN.

Results In the cadaver study, nerve transfers from ECRB to AIN, brachialis to AIN, and ECRB to ulnar-FDP were all feasible. The transfer from the brachialis to ulnar-FDP was not possible. Mean myelinated axon counts of AIN, brachialis, ulnar-FDP, and ECRB were 2,903 $\pm$ 1049, 1,497 $\pm$ 606, 753 $\pm$ 364, and 567 $\pm$ 175, respectively. The donor-to-recipient axon count ratios of ECRB to AIN, brachialis to AIN, and ECRB to ulnar-FDP were 0.24 $\pm$ 0.15, 0.55 $\pm$ 0.38, and 0.98 $\pm$ 0.60, respectively. The distance from coaptation of the ECRB to the ulnar-FDP muscle entry was shorter than for the other nerve transfers (54 $\pm$ 14.29 mm). At 18 months, there was restoration of flexion in all fingers and functional improvement from double nerve transfer of the brachialis to the AIN and the ECRB to the ulnar-FDP.

Conclusions Restoration of all finger flexion may be feasible by the ECRB to ulnar-FDP and brachialis to AIN double nerve transfer.

Clinical relevance Double nerve transfer can be used in C6-C7 spinal cord injury and patients with lower arm–type brachial plexus injury who have no finger flexion but have good brachialis and ECRB. *(J Hand Surg Am. 2018;43(10):920–926. Copyright © 2018 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Brachial plexus injury, nerve transfer, spinal cord injury, tetraplegia, ulnar nerve.

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TRAUMATIC SPINAL CORD INJURY (TSCI) is a devastating occurrence. Restoration of arm and hand movement in tetraplegia appears to be the highest priority in TSCI cases.[1] The recent development of distal nerve transfers has provided new options for tetraplegia treatment. Nerve transfer, including multiple nerve transfers in a single stage,[2–4] offers several benefits such as preserving biomechanical muscle function and obviating the need for prolonged immobilization.

Among nerve transfers for finger flexion restoration, common donor nerves are the brachialis branch (C5-C6)[3,5] and the extensor carpi radialis brevis (ECRB) branch (C6).[6,7] The anterior interosseous nerve (AIN) (C8-T1)[5,6] is the recipient nerve for finger flexion and can restore the flexor of the thumb and flexor digitorum profundus (FDP) of the index and middle fingers (AIN-FDP). Another potential recipient nerve that has not received attention for finger flexion is the FDP branch of the ulnar nerve (C8-T1), which supplies the ulnar-FDP.

Previous research[8] showed that the success of a nerve transfer depends on having a donor-to-recipient axon count ratio of more than 0.7:1, a short distance from the coaptation site to the target structure[9] and a relatively easy, tensionless nerve repair.[10] We performed a study to explore the feasibility of restoring all finger flexion after a cervical spinal cord injury using the AIN and ulnar-FDP branches as recipient nerves and the brachialis and ECRB branches as donor nerves. We also report on the outcome of conducting 4 nerve transfers bilaterally, including double nerve transfer of the brachialis to the AIN and the ECRB to the ulnar-FDP in a patient with a complete C6 TSCI.

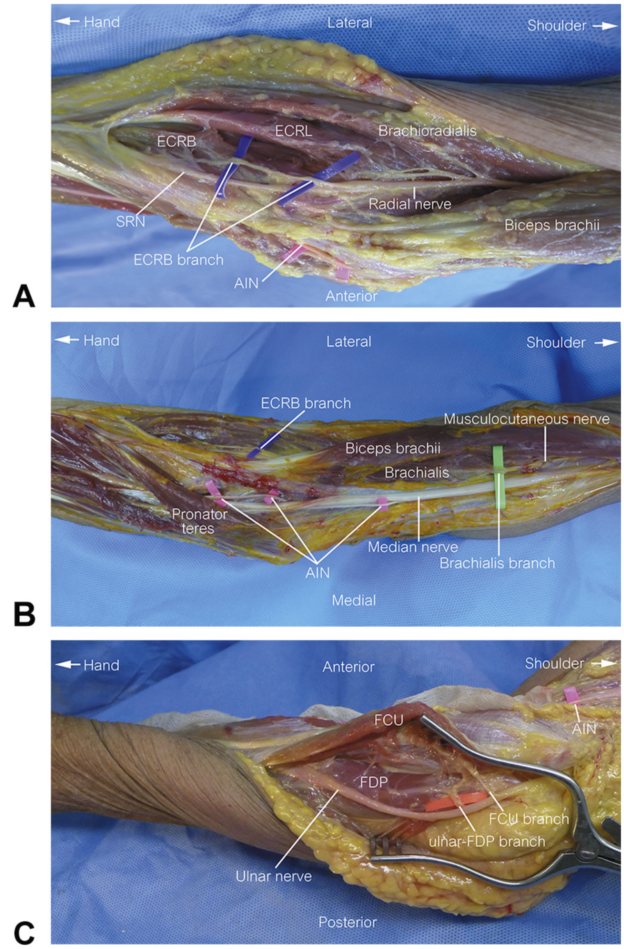

FIGURE 1: Anatomical study. Dissection of right upper limb. **A** Anterolateral aspect, ECRB branch (purple background) arises distal to the extensor carpi radialis longus (ECRL) and brachioradialis. **B** Anterior aspect. The AIN (pink background) arises from the median nerve at the cubital fossa, extending proximally inside the median nerve. **C** Medial aspect of the elbow. The ulnar-FDP (orange background) arises from deep in the ulnar nerve dissected between two heads of the flexor carpi ulnaris (FCU). SRN, superficial radial nerve.

MATERIALS AND METHODS

Anatomical study

The protocol of this research was approved by the ethics committee of our institution. We dissected 22 upper extremities under ×3.3 magnification in 4 areas including the ECRB at the elbow (Fig. 1A), the brachialis branch in the upper arm, the AIN from the wrist to the upper arm (Fig. 1B), and the ulnar-FDP at the elbow (Fig. 1C). After identifying these nerve branches, the ECRB branch was transferred to the AIN and the ulnar-FDP branch below the elbow. The brachialis branch was transferred to the AIN portion of the median nerve and the ulnar-FDP portion of the ulnar nerve above the elbow (Fig. 2). The distance between the nerve coaptation site and the recipient nerve entry into the target muscle was measured using a Vernier digital caliper. A total of 80 nerve specimens, each 20 mm long, were embedded in paraffin, sectioned transversely, and stained with a combination of hematoxylin-eosin and Luxol fast blue.[11] Myelinated axons were counted and the cross-sectional fascicular area of each nerve was measured.

Clinical study

An 18-year-old patient had experienced a cervical spine fracture dislocation in a motor vehicle accident 8 months before undergoing nerve transfers to restore elbow extension and hand motion. The patient was diagnosed as complete cervical TSCI, scored as C6A according to the International Standards for Neurological Classification of Spinal Cord Injury (revised