Targeted Muscle Reinnervation for Partial Hand Amputation

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Background: Targeted muscle reinnervation for the treatment of symptomatic neuromas after upper limb amputation has been described for shoulder disarticulation and for transhumeral and transradial amputations. Early clinical outcomes are promising and demonstrate a statistically significant reduction in phantom limb pain and a decrease in residual limb pain.

Methods: We performed a cadaver dissection of the motor branches arising from the median and ulnar nerves to assess whether this technique could be applied to symptomatic neuromas after partial hand or finger amputations.

Results: After identification of all branches under 4.5x loupe magnification, we performed simulated transfers of digital nerves to lumbrical motor branches, common digital nerves to lumbrical motor branches or the recurrent motor branch, and the common sensory portion of the ulnar nerve to a hypothenar motor branch.

Conclusions: The proximity of all sensory nerves to motor branches and the numerous redundant motor nerve targets available support our hypothesis that targeted muscle reinnervation is possible after partial hand or finger amputation. Further studies will be required to refine clinical indications and evaluate outcomes.

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INTRODUCTION
Symptomatic neuroma formation after a partial hand or finger amputation can interfere with the function of the residual limb for activities of daily living and prosthetic use. Although the incidence of symptomatic neuroma formation after partial hand amputation has not been studied, 2 recent studies that evaluated symptomatic neuroma formation after isolated digit amputation found incidences of 6.6% and 7.8%.1,2

Surgical treatment of symptomatic neuromas can be considered if nonoperative modalities are unsuccessful. In a retrospective study of 1083 patients who underwent primary digital amputation after traumatic injury, symptomatic neuroma formation did not correlate with the method of surgical management of the nerve ends, including transection and retraction (66%) or transection and burying the nerve end in the bone (26%), muscle, or fat (8.5%).1 Based on this and other similar studies, there is no accepted “gold standard” surgery for treatment of symptomatic neuromas. However, a recent randomized trial that compared targeted muscle reinnervation (TMR) to “traditional” implantation of the nerve end into muscle demonstrated a statistically significant reduction in phantom limb pain and nonsignificant reduction in residual limb pain (symptomatic neuroma) after upper- and lower-extremity amputations.3,4

We hypothesized that TMR could also be used for neuroma management after partial hand or finger amputation. Our hypothesis is supported by a case report of TMR after a partial hand amputation by Daugherty et al and previous cadaveric studies that described a consistent innervation patterns to the intrinsic muscles of the hand.5–7 Here we report the findings of a single cadaver dissection that was done to better evaluate the anatomy of the innervation to the intrinsic muscles as possible nerve transfer recipients for TMR and simulate several possible transfers that could be done for various levels of digital or hand amputation.

CADAVER DISSECTION
The terminal median and ulnar nerves of a fresh cadaver were dissected using microsurgical instruments under 4.5x loupe magnification. An extended carpal tunnel incision was designed with a distal radial extension to expose the radial lumbricals and terminal deep ulnar motor branch and a proximal ulnar extension to dissect the ulnar nerve branches to the ulnar lumbricals, interossei, and hypothenars. The nerves, including all sensory
and motor branches, were dissected in a proximal to distal fashion until the sensory nerves reached the digital-palmar crease and all motor branches entered the muscle belly.

The median nerve was dissected first. No branches from the recurrent motor nerve could be identified without extensive division of the overlying muscle fibers. The common digital nerves arising from the median nerve were then dissected, and small motor branches to the superficial surface of the lumbricals to the index (L1), middle (L2), and ring finger (L3) were seen arising from the ulnar side of the nerves (Fig. 1).

The ulnar nerve was then dissected in a similar fashion. One small branch was seen arising from the common sensory nerve and entered the thin overlying palmaris brevis muscle (Fig. 2). The deep motor branch was dissected, and several motor branches to the hypothenar muscles, third and fourth interossei, and ulnar 2 lumbricals (L3 and L4) were identified (Fig. 3). The deep motor branch was then followed across the palm to where additional branches to the second interossei were seen, before it entered the adductor pollicis muscle (Fig. 4). Division of the adductor pollicis muscle allowed for further dissection of the nerve, which demonstrated 2 distinct nerve branches to the 2 heads of the adductor pollicis and the terminal branch to the first dorsal interosseous.

Simulated TMR transfers for a range of possible symptomatic neuromas were then performed, including radial digital nerve to the index to L1, common digital nerve to the thumb to the recurrent motor nerve branch, index/middle sensory nerve to L2 motor branch, small finger radial digital nerve to palmaris brevis motor branch, and ulnar common sensory nerve to hypothenar motor branch.

**DISCUSSION**

After partial hand or finger amputations, neuroma pain can interfere with use of the hand for activities of daily living and prosthetic wear. We have shown that TMR after finger or partial hand amputation is anatomically and surgically possible, with a number of motor nerve branches to the intrinsic muscles of the hand available as motor targets. For neuromas arising from the median nerve, possible recipients include the recurrent motor branch and nerves to L1, L2, and L3 (median innervated in 72% of specimens) superficially, as well as the adductor pollicis branches and first and second interosseous branches in the deeper plane. On the ulnar innervated side of the hand, potential recipients include the branch to palmaris brevis in the superficial plane, as well as the branches to the hypothenar muscles, third and fourth palmar and dorsal interossei, L3, and L4 in the deeper plane (Fig. 1).

![Fig. 1. Dissection of the median nerve. A, Recurrent motor branch. B, Digital nerves to thumb. C, Index radial digital nerve. D, Nerve to L1 arising from C. E, Common digital nerve to index and middle. F, Nerve to L2 arising from E.](image1)

![Fig. 2. Dissection of the sensory portion of the ulnar nerve. A, Common sensory nerve. B, Branch to palmaris brevis. C, Common digital nerve to ring and small fingers. D, Ulnar digital nerve to small finger.](image2)
Every partial hand amputation is unique, and residual hand function and sources of prosthetic control need to be considered when determining which motor nerve branches are possible recipients for TMR. Transmetacarpal level amputations do not require intrinsic function, except for prosthetic control by surface electromyography (EMG) recording electrodes, usually placed over the second dorsal interosseous (hand open) and flexor or abductor digiti minimi (hand close). These should be preserved. All other motor branches are potential recipients in these patients. If the metacarpophalangeal joint is preserved after finger amputation, transfer of the digital nerve(s) to the lumbrical motor branch(es) with preservation of the interossei would be least likely to interfere with residual hand function.

Although we have demonstrated that the motor branches to the intrinsics can be dissected surgically, and that TMR after finger or partial hand amputation is anatomically possible, there are several limitations to this report. Although the anatomy was consistent with previous studies, unanticipated individual anatomic variations may be encountered. We were unable to stimulate the dissected nerves to confirm their identity and function. Prosthetic advancements, including independent finger motion driven by the interossei, in combination with the possibility of implantable EMG, may impact donor nerve selection. Finally, although an initial case report has demonstrated promising results, additional clinical studies will be required to evaluate indications and outcomes.

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