SCIENTIFIC ARTICLE

Nerve and Free Gracilis Muscle Transfers for Thumb and Finger Extension Reconstruction in Long-standing Tetraplegia

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Purpose With spinal cord injuries, muscles below the level of the lesion remain innervated despite the absence of volitional control. This persistent innervation protects against denervation atrophy and may allow for nerve transfers to treat long-standing lesions within the spinal cord. We tested the hypothesis that in chronic spinal cord lesions, muscles remained viable for reinnervation.

Methods To test this hypothesis, we operated on 7 patients with tetraplegia to reconstruct thumb and finger extension after a mean interval of 5 years since injury. During surgery, if electrical stimulation of the posterior interosseous nerve (PIN) produced muscle contraction, the nerve to the supinator (NS) was transferred to the PIN. If no contractions were demonstrated, the muscles of the extensor compartment of the forearm were replaced via a free gracilis transfer with innervation supplied by the NS.

Results After an average of 26 months, M3 recovery of thumb and finger extension was observed in the 3 upper limbs from the 2 youngest patients who underwent a nerve transfer. None of the free gracilis-treated patients achieved scores above M2.

Conclusions In our youngest patients aged 27 and 34 years, who were operated on 6 years after spinal cord injury, transfer of the NS to the PIN partially restored hand span. *(J Hand Surg Am. 2016;■(■):■–■. Copyright © 2016 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic V.

Key words Nerve transfer, tetraplegia, free muscle transfer, spinal cord injury.

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In patients with tetraplegia, nerve transfer entails connecting an expendable donor nerve with some component of the motor neuron pool above the lesion where the patient has volitional control to an intact but nonfunctional recipient nerve within the motor neuron pool at or below the level of the spinal cord lesion, to restore volitional control to these muscles.[1]

In 1991, Krasuski and Kiwerski[2] reported the first series of patients with tetraplegia for whom nerve transfers were used to reconstruct hand grasp function. In 42 patients within 1 year of injury, the musculocutaneous nerve was transferred to the median nerve in the right upper arm. After surgery, 26 of the 42 patients were not able to grasp objects without help. In

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no case was it possible to restore precise function.[2] Reasons for these limited results might have been the nonselective nature of the nerve transfers and their distance from the target muscles. In midcervical tetraplegia sensation in the territory on the median nerve is preserved.[3] Consequently, sectioning the median nerve for transfer invariably downgraded sensation in the hand. Driven by brachial plexus surgery, nerve transfers progressed and the concept of distal nerve transfers evolved. Instead of transferring entire nerves far from the targets, surgeons now transfer a pure donor motor branch to a pure recipient motor branch close to the motor end plates.[4]

More recently, the concept of distal motor nerve transfers was successfully applied to the reconstruction of elbow, thumb, and finger extension in a series of patients with spinal cord injuries operated on at an average of 7 months after paralysis.[5]

After a spinal cord injury, a mixture of central and peripheral nerve paralysis occurs. The peripheral paralysis that occurs after the death of motor neurons results in rapid muscle atrophy as a consequence of denervation (ie, lower motor neuron syndrome).[5] Such paralysis should be operated on within a year of the initial injury.[5] On the other hand, central paralysis occurs because of long tract spinal cord lesions (ie, upper motor neuron syndrome). Central paralysis prevents muscle denervation because Wallerian degeneration does not occur provided the axon remains in contact with the cell body.[6] From a hypothetical point of view, central palsies could be operated upon even years after the accident, because muscle innervation is preserved.[6]

The motor neuron pool of the nerve to supinator (NS) is located at the C5-C6 spinal cord level, at or above the site of spinal cord injury in a patient with midcervical tetraplegia.[7] The supinator muscle and the radial wrist extensors share the same metamere. In midcervical tetraplegia, if wrist extension is preserved the NS is available for transfer.[7] The motor neuron pool of the posterior interosseous nerve (PIN) is located at or below the site of lesion, at C7-T1 metameres.[8,9] Depending on the extent of the spinal cord lesion or cavitation and consequent neuronal death, paralysis of the PIN varies from central to a peripheral type. After a midcervical tetraplegia, because of the widespread distribution of motor neurons of the radial nerve along the brachial plexus,[10] the radial nerve carries degenerated motor fibers, preserved motor fibers without supraspinal control, and preserved motor fibers under voluntary control.

In the current study, we tested the hypothesis that in chronic spinal cord lesions, muscles affected by central palsies (ie, upper motor neuron lesion) remained viable for reinnervation. We performed transfers of the NS to the PIN in patients with long-standing spinal cord injury in whom electrical stimulation of the PIN produced muscle contractions (ie, central palsy). In another group of patients, intraoperative electrical stimulation of the PIN produced no muscle contraction (ie, peripheral palsy) so that a free gracilis muscle, which was affected by central palsy, was transferred to the extensor compartment of the forearm and reinnervated by the NS.

PATIENTS AND METHODS

In advance of any data collection, the local ethics committee approved the protocol of the study. Patients provided verbal informed consent before participation, in accordance with the Declaration of Helsinki guiding biomedical research involving human subjects.

Seven male patients, median age 40 years (range, 28−59 years), who had sustained a complete cervical spinal cord injury, underwent surgery for thumb and finger extension reconstruction a median of 5.5 years after the accident. Only the right upper limb was operated upon in 3 patients because the left side had no wrist extension preservation. If wrist extension is absent, the NS is paralyzed but the first surgical priority is wrist extension reconstruction. In one patient, wrist extension was preserved on both sides and surgery was performed bilaterally. In 3 patients only the right side was operated on because a free gracilis transplant was carried out on the contralateral side. All patients had supple joints and full paralysis of finger flexion and extension. Supinator muscle contraction could be palpated during resisted supination in all patients because of atrophy of the extensor digitorum communis (EDC). Table 1 lists patient data. Besides thumb and finger extension reconstruction, in patient 2 we reconstructed finger flexion by transferring the tendon of the extensor carpi radialis to the flexor digitorum profundus and flexor pollicis longus, in patient 3 we transferred the tendon of the brachioradialis to the flexor digitorum profundus and flexor pollicis longus, and in patient 7 we transferred the nerve to the extensor carpi radialis brevis to the anterior interosseous nerve.

The selection of patients for nerve transfer or free muscle transfer was based on intraoperative electrical stimulation of the PIN. The PIN was stimulated using an insulated 21-gauge needle (Contiplex D; B. Braun Melsungen AG, Melsungen, Germany) connected to a nerve stimulator (Stimuplex HNS 11; B. Braun