Transfer of the teres minor motor branch for triceps reinnervation in tetraplegia

Case report

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In a case involving tetraplegia and paralysis of elbow extension, the authors transferred teres minor branches to the nerve of the triceps long head. Surgery was performed bilaterally 9 months after the patient sustained a spinal cord injury. Fourteen months postoperatively, elbow extension was complete (British Medical Research Council Score M4). Harvesting of the teres minor motor branch produced no deficits in shoulder function. In patients with tetraplegia, nerve transfer seems to be a promising new alternative for elbow extension reconstruction.

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Key Words • tetraplegia • nerve transfer • elbow extension

In patients with tetraplegia, elbow extension is of paramount importance. The ability to extend the elbow results in functional gains, including an increase in workspace, the ability to perform pressure-relief maneuvers, better manual wheelchair propulsion, and independent transfers. Elbow extension against gravity also enables activity above the shoulder level, such as retrieving objects from an elevated shelf.1,6

With conventional methods—transferring either the posterior deltoid or biceps muscle to the triceps muscle—the vast majority of patients only recover enough strength to resist gravity.7 Despite their widespread use in brachial plexus reconstruction, distal nerve transfers have only recently been applied in tetraplegia. We have successfully transferred the supinator motor branch to the posterior interosseous nerve to reconstruct thumb and finger extension.4 In a recent anatomical study, we observed that either the teres minor motor branch or the posterior deltoid motor branch is suitable for transfer to triceps motor branches.3 In the present case, we report using the teres minor motor branch to reconstruct elbow extension in a patient with tetraplegia.

Case Report

In advance of any data collection, the protocol of the present study was approved by the local ethics committee. The patient provided his written informed consent prior to participation, in accordance with the Declaration of Helsinki guiding biomedical research involving human subjects.

History and Examination. This 21-year-old man sustained a cervical SCI in a 2-story fall. The injury was complete, affecting perineal sensation and the bulbocavernous reflex. Shortly after his injury, the patient underwent surgery for spinal stabilization. Eight months after his accident, the patient presented to our department seeking assistance to improve his upper-limb function. At the time of his initial examination, the patient was sitting in a wheelchair, and exhibited no lower-limb motion. He had full motion and strength in both shoulders. Elbow flexion on the right and left sides scored M5 according to the BMRC Scale;8 his biceps, brachialis, and brachioradialis muscles were all functional. Triceps function was absent (BMRC Grade M0 on both the right and left sides). Supination was Grade M5 with the elbow extended or totally flexed, bilaterally. In both forearms, pronation was possible, but weak (Grade M3). Flexor carpi radialis strength was Grade M3 on the right and M2 on the left. Wrist extension was Grade M4 bilaterally. There was no active thumb or finger flexion/extension. All the intrinsic muscles of his hand were affected. Hand sensation was largely preserved. Mild spasticity was observed involv-

Abbreviations used in this paper: BMRC = British Medical Research Council; EMG = electromyography; SCI = spinal cord injury.

This article contains some figures that are displayed in color online but in black and white in the print edition.
ing the finger flexors. No motor or sensory function was preserved in the sacral segments. Our patient's findings placed him in Group 2 of the International Classification system for muscle function in tetraplegia. On preoperative EMG, the triceps, teres minor, and deltoid muscles exhibited no abnormalities on either side.

Operation. Nine months after his accident, the patient underwent bilateral transfers of the teres minor motor branch to the triceps long head motor branch. General anesthesia was used without muscle relaxants. The patient was placed in the supine position. An incision was outlined in the axillary region. To avoid scar retraction over the tendon of the latissimus dorsi muscle, a triangular skin flap was outlined (Fig. 1). In the arm, the brachial vein was visualized and protected. The tendon of the latissimus dorsi muscle was located and exposed completely. After visualization of its medial margin, the humeral head was palpated and the axillary nerve identified by palpation. The posterior circumflex humeral vessels were visualized and the axillary nerve dissected. A retractor was placed on the tendon of the latissimus dorsi to retract it laterally, thereby exposing the quadrangular space. The anterior and posterior divisions of the axillary nerve were identified, together with the branch to the triceps long head motor branch. Gen.

Skin closure, the incision was infiltrated with a solution of local anesthetics for postoperative pain control. This surgery procedure was performed bilaterally.

Postoperative Course. After surgery, only a sling was used, which was maintained for 10 days. Because immobilization was not rigid, during this period the patient was encouraged to perform his normal activities. Ten days after surgery, the patient resumed physiotherapy sessions for his SCI. Only when the first evidence of triceps contraction was perceived did physiotherapy sessions focus on enhancing strength. Exercises began with the patient in the sitting position, instructed to externally rotate his shoulder while attempting to extend the elbow with his head turned toward the same side. This was done to mimic the tonic neck reflex, which involved contraction of a group of agonist muscles, particularly external rotators and elbow extensors.

During the postoperative period, we did not detect any drawbacks stemming from sacrificing the teres minor motor branch. There was no decrease in external rotation strength. Active contractions of the triceps long head were perceived in about the 5th postoperative month. Fourteen months after surgery, elbow extension was complete, with BMRC Grade M4 strength on both the left and right sides (Fig. 4). Elbow extension was under full voluntary control and could be executed with the shoulder either externally or internally rotated (Fig. 4).

Discussion

Transferring the teres minor motor nerve successfully restored active elbow extension in our patient with tetraplegia. In addition to the good functional improvement, the patient experienced only a brief period of postoperative immobilization, an important consideration in individuals with tetraplegia. This benefit contrasts with the prolonged, strict elbow immobilization that is necessary when the posterior deltoid muscle is transferred to the triceps. In this situation, full elbow flexion is only permitted 8 weeks after surgery. Rehabilitation time is long and is a significant challenge to the patient and family. During this period, the patient is rendered totally dependent; this is a tremendous drawback of musculotendinous surgery in patients with tetraplegia, such that some patients give up on their reconstruction program.

Our anatomical dissections have demonstrated that not only the teres minor motor branch, but also the posterior deltoid branch is suitable for reinnervation of the triceps muscle. However, we elected to use only the teres minor branch because of the 9 months that had elapsed between the initial injury and surgery. The posterior deltoid muscle, left untouched, still would be available for muscle transfer for reconstruction if our nerve transfer approach failed completely, or for augmentation in the case of partial recovery.

If surgery had been performed earlier, we probably would have considered using the posterior deltoid motor branch, or part of it, to reinnervate the latissimus dorsi or the triceps medial head. Reinnervation of the latissimus dorsi would be of interest with respect to improving the patient's self-transfer capability. The duration of time between the initial injury and reinnervation is of paramount importance in peripheral nerve surgery, because of target muscle and nerve pathway denervation. In tetraplegia, however, target muscles and pathways are not denervated; hence, successful reinnervation is potentially feasible even when performed later. Despite this hypothesis, Krauski and Kiwerski observed time-dependent results in the reinnervation of finger flexors following transfer of
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the musculocutaneous nerve to the median nerve in patients with tetraplegia. Their surgery involved the transfer of large nerve trunks very distant from the targets, with the potential for aberrant reinnervation and permanent disturbance of hand sensation. Hence, their worst results, in patients operated upon more than 3 months after trauma, could have been avoided by means of selected distal nerve transfers, as we have reported here and elsewhere. Millesi also observed that age interfered with outcomes, as with any nerve repair. Experimental investigations are needed to clarify if distal nerve transfers can be applied to chronic spinal cord lesions.

In general, it is recommended that tendon transfer in tetraplegia be delayed at least 1 year postinjury to ensure that any and all spontaneous recovery already has occurred. We do not believe that our having performed surgery before 1 year postinjury could have overshadowed spontaneous recovery in our patient, because major progress in spontaneous reinnervation generally occurs within the 1st 6 months of an SCI. As a general rule, Lamb and Chan believe that, if a muscle is completely paralyzed during the initial assessment and is the same 1 month later, it is unlikely that there will be any significant spontaneous recovery in that muscle. To be more precise, there is virtually no chance that a muscle fully paralyzed 6 months after trauma will spontaneously regain active useful motor power over the subsequent 6 months. Hence, we consider 6 months postinjury to be the ideal time for nerve transfer procedures in patients with tetraplegia. Having said this, earlier surgery should be considered if EMG demonstrates muscle denervation resulting from motoneuronal death at the site of the SCI. Moreover, attempting triceps reinnervation via the long head motor branch does not invalidate eventual spontaneous reinnervation from nerves of the lateral and medial head branches, which receive their motoneuronal supply from the upper levels of the cervical spinal cord.

In our patient, teres minor motor branch transfer for triceps reinnervation yielded marked recovery of elbow extension without any donor site deficits. As observed herein, the infraspinatus muscle compensates for any deficits in external rotation following the sacrifice of teres minor innervation. Moreover, the teres minor muscle is not used for transfers in patients with tetraplegia. Additionally, sacrificing the teres minor nerve does not eliminate the option of later transfers of the biceps or posterior deltoid muscle to the triceps tendon to enhance results after only partial recovery, or as rescue in the case of total procedural failure. The ideal candidate for the teres minor motor nerve transfer to the triceps long head is the individual with functional C-6 tetraplegia, with active contractions of the teres minor muscle on physical examination and without signs of denervation on the EMG. During surgery, direct stimulation of the teres minor motor branch should produce vivid muscle contractions; if this is not the case, the posterior deltoid motor branch is an alternative donor for transfer.

![Fig. 2. Intraoperative view of the transfer of the teres minor (TM) motor branch to the triceps long (TL) head motor branch. Note the adequate diameter matching between the nerve stumps. Also, observe that coaptation is tension free. Ax = axillary nerve; IB = intercostobrachial nerve; LD = latissimus dorsi tendon; RN = radial nerve; TMa = teres major.](image)

![Fig. 3. Schematic representation of the surgical procedure. Arrowhead indicates the coaptation site of the teres minor motor branch with the triceps long head motor branch.](image)
Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Bertelli, Ghizoni. Acquisition of data: Bertelli, Ghizoni. Analysis and interpretation of data: all authors. Drafting the article: Bertelli. Critically revising the article: Bertelli, Ghizoni. Reviewed final version of the manuscript and approved it for submission: all authors.

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