Free Functional Muscle Transfers to Restore Upper Extremity Function

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KEYWORDS

• Muscle transfer • Microsurgery • Free tissue transfer • Brachial plexus • Nerve regeneration • Nerve transfer • Nerve graft • Intercostal nerves

KEY POINTS

- Free functional muscle transfer provides an option for functional restoration once target muscle re-innervation is no longer feasible.
- Critical requirements include a functioning donor motor nerve, proper tension insetting, and physical therapy for motor re-education and strengthening.
- Adequate time should be provided for nerve regeneration if performed in 2 stages, with a long nerve graft.

INTRODUCTION

Free functional muscle transfer (FFMT) provides a reconstructive option for functional improvement in the setting of severe upper extremity nerve and brachial plexus injuries. With the advent of microsurgery, followed by the development of free muscle and musculocutaneous flaps for wound coverage,[1] an FFMT expands the use of free tissue transfer for dynamic reconstruction. Paired with nerve transfer, it provides an opportunity to restore volitional control of the upper extremity after nerve injury.

FFMT has numerous requirements for success. First, there must be an expendable donor muscle that is available for transfer. Second, an expendable donor motor nerve outside of the zone of injury must be available in proximity to the recipient site to power the transferred muscle. Next, proper insetting of the muscle is required to maintain an ideal muscle length-tension ratio.[2] Last, cooperation of the patient with the surgical team and a dedicated hand therapist postoperatively is essential for proper splinting and motor re-education to maximize function.

This review outlines the indications for FFMT, focusing on the reconstructive goals for FFMT in brachial plexus palsy, and reviews commonly used donor muscles and nerves. The authors' preferred approach to these complicated nerve injuries is also discussed.

INDICATIONS

FFMT is a reconstructive option after 3 broad groups of injury: focal traumatic or surgical loss of a particular muscle or muscle groups, Volkmann ischemic contracture, and brachial plexus injury.

Focal Muscle Loss

Reconstruction using FFMT has been described for upper extremity reconstruction after tumor extirpation and traumatic injuries to muscle

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groups.[3] Donor muscles include the gracilis, extensor digitorum brevis, flexor carpi ulnaris (FCU), and latissimus dorsi muscles to reconstruct functions, such as thenar function, shoulder adduction, and wrist and finger extension.[4–7] The focal nature of tissue loss in patients with traumatic or postoncologic soft tissue excision allows for the availability of a larger variety of donor nerves closer to end-target to power the FFMT. Often, the native nerve to the missing muscle group is preserved and available for direct coaptation.[3]

Volkmann Ischemic Contracture

FFMT for the reconstruction of finger flexion was first described in 1976 using the pectoralis major muscle and then in 1978 using the gracilis muscle after devastating traumatic soft tissue loss or after Volkmann ischemic contracture.[8,9] Independent finger and thumb flexion has been described using gracilis FFMT by splitting the muscle in a bipennate fashion and performing internal neurolysis of the gracilis motor branch of the obturator nerve to provide 2 independently innervated slips that can be tenodesed to the flexor pollicis longus (FPL) and flexor digitorum profundus (FDP) as separate motors.[10] A Volkmann ischemic contracture has unique considerations, including soft tissue constraints from the extent of injury and the pediatric population, and considerations for growth in the future that are beyond the focus of this article but are covered in-depth elsewhere.[11]

Brachial Plexus Palsy

FFMT enables surgeons to restore upper extremity function in patients with brachial plexus palsy who have either exhausted potential nerve transfer options and have persisting deficits, delayed presentation, or complete plexus injuries.

Following the report of Manktelow and McKee[9] of the use of FFMT for finger flexion, Ikuta and colleagues[12] described the reconstruction of elbow flexion in late brachial plexopathy in 1979. Few surgical options existed for the late or complete brachial plexus injury before those studies.[13] Primary excision and grafting in brachial plexus injuries affecting hand function had disappointing results because the surgical reconstruction was too distant from the target muscles to provide meaningful reinnervation before motor endplate deterioration. Terzis and Kostopoulos[13] described the historical approach by Seddon[14] to severe plexopathy, which suggested that the aim of early surgery was to clarify the level of injury and recommended amputation of the extremity in injury patterns without recovery potential.

The development of the FFMT allowed a shift in focus of brachial plexus surgery. Although the principles of shoulder stabilization and restoration of elbow flexion remain unchanged, increased effort is now focused on restoring elbow extension and hand function as well. Nerve transfers are often used for restoration of proximal targets, including shoulder function, elbow flexion, and extension, while FFMT is important to restore hand function. Some centers advocate for FFMT to restore both elbow flexion and finger flexion or extension in a single muscle transfer.[15–19] The multistage approach to brachial plexus reconstruction using combinations of nerve transfers and FFMT has now replaced primary excision and grafting as the preferred technique for severe adult brachial plexus injury.[20]

PATIENT EVALUATION

A complete history and physical examination, including mechanism of injury and concomitant trauma, such as fractures, vascular injuries,[21] and brain injury,[22,23] are important in determining which reconstructive options are available. A brachial plexus diagram to record testing of all major muscle groups organized by nerve roots is helpful to identify the level of injury, severity, and recovery (Fig. 1). Muscle strength is documented using the British Medical Research Council (MRC) scale.[24] Evaluation of sensation using 2-point discrimination can provide insight into preganglionic or postganglionic level of injury. Identification of Horner syndrome (eyelid ptosis, miosis, and anhidrosis) signifies likely avulsion of the T1 root. Possible donor nerves of intraplexal and extraplexal origin should also be assessed.

Key diagnostic tests are obtained early, including chest radiographs, extremity radiographs (if humerus or forearm fractures occurred at the time of injury or patient has history of previous bony fixation), electromyography (EMG), and nerve conduction studies. The chest radiograph will identify rib fractures and the functional status of the phrenic nerve.

Electrodiagnostics, including EMG, are ordered outside of the acute period, usually at 3 months and immediately preoperatively for the first stage of brachial plexus intervention. Evidence of denervation (muscle fibrillation) without evidence of reinnervation (motor unit potentials) indicates more severe injury that requires operative intervention for functional return.[25] EMG should also evaluate potential donor nerves for nerve transfers or FFMT.[26] The investigators ask for specific evaluation of the trapezius, pectoralis major, and latissimus dorsi because they provide excellent nerve donors when available.[27]