Nerve Transfers to Restore Elbow Function

Liselotte F. Bulstra, BS[a,b], Alexander Y. Shin, MD[a,*]

KEYWORDS

• Nerve transfers • Elbow flexion • Elbow extension • Proximal nerve injury • Nerve root avulsion • Brachial plexus injury

KEY POINTS

- Elbow flexion is considered the most important function of the upper limb.
- Nerve transfers allow for conversion of a proximal nerve injury to a more distal injury.
- The functional gain of the recipient nerve should be greater than the expected functional loss from the donor nerve.
- The use of interpositional nerve grafts to bridge gaps in transferred nerves should be avoided.
- Nerve transfers can also be used for innervation of free-functioning muscle transfers.

INTRODUCTION

Elbow flexion is considered the most important function to restore in the paralyzed upper extremity as it provides positioning of the hand in a useful position for daily activities. Elbow extension is necessary to stabilize the elbow, to achieve a stabile grasp, and for any activity that requires the arm to be lifted above horizontal position. Moreover, in cases of insufficient (M0 to M2) recovery of elbow flexion with primary surgery, the reinnervated triceps could be transferred to provide this function.[1]

Causes of loss of elbow function include traumatic brachial plexus injury, spinal cord injuries, and injury to the nerves innervating the elbow flexors and/or extensors such as stab wounds, gunshot injuries, radiation-induced neuropathies, and brachial plexus birth palsy.[2,3] When direct nerve repair is not possible, and nerve grafting is not expected to provide satisfactory results, nerve transfers are a viable option. The role of nerve transfers has expanded drastically in the past 15 years, providing a commonly used treatment strategy for the restoration of elbow function, being used for direct neurotization of target muscles as well as neurotization of free-functioning muscle transfers (FFMTs).[4,5]

HISTORICAL PERSPECTIVE

Nerve transfers were described in the early 20th century by Harris[6] and Tuttle,[7] who in 1913 reported coaptation of the anterior terminal branch of C4 to the split upper trunk. Unfortunately, results were not well recorded in these early cases.

A seminal advancement was the application of intercostal nerves for the neurotization of the musculocutaneous nerve described by Seddon[8] in 1961. The unsatisfactory results were secondary to the interposition nerve grafts, and subsequently Tsuyama and Hara[9] modified the technique such that direct intercostal to motor biceps branch could be performed. The use of intercostal nerves to innervate the musculocutaneous nerve was further popularized by Narakas,[10] and good results have been reported by multiple groups.[11–15] The challenge of restoration

No conflicts of interest are declared by any author on this study.
Source of Funding: No disclosures of funding were received for this work.
[a] Department of Orthopedic Surgery, Mayo Clinic, 200 First Street Southwest, Rochester, MN 55905, USA; [b] Department of Plastic, Reconstructive and Hand Surgery, Erasmus Medical Center, 's-Gravendijkwal 230, 3015 CE Rotterdam, The Netherlands
* Corresponding author.
E-mail address: shin.alexander@mayo.edu

Hand Clin 32 (2016) 165–174
http://dx.doi.org/10.1016/j.hcl.2015.12.005
0749-0712/16/$ – see front matter

hand.theclinics.com

of elbow flexion worldwide resulted in many groups exploring the potential of different donor nerves, expanding the options that were already described by Lurje[16] in 1948, including the long thoracic nerve, medial and lateral pectoral nerve, radial nerve, and thoracodorsal and subscapular nerve.[17–19] More recent developments in nerve transfers for elbow function, the ulnar nerve fascicle transfer as described by Oberlin,[20] and transfer of fascicles of the median nerve as described by Mackinnon and colleagues[21] successfully moved the coaptation site more distal, further improving functional outcome. Over the past decade, many of these options have been modified and refined resulting in more reliable restoration of elbow function.

INDICATIONS AND CONTRAINDICATIONS

Nerve transfers are indicated in patients with no hope for spontaneous recovery or improvement of their nerve injury. Possible indications and contraindications are described in **Table 1**.[22,23] It is important to note that strategies of reconstruction have evolved and changed and will continue to do so. Some authors prefer not to explore the brachial plexus, stating that the surgery is difficult, especially in a scarred bed, and proceed to nerve transfers, while others always explore the brachial plexus to evaluate for viable nerve roots that can be used with nerve grafts to critical targets in lieu of nerve transfers. Although this controversy will remain until better outcome studies are performed, it is the authors' philosophy to explore every acute (<6–7 months after injury) brachial plexus injury and evaluate the nerve roots. If a viable root exists, it will be used with nerve grafts to target shoulder girdle musculature. If a second viable root exists, it will be used with nerve grafts to target elbow flexion or extension.

PRINCIPLES OF NERVE TRANSFERS

The principle of nerve transfers is the coaptation of one or more healthy (Medical Research Council [MRC]>4) but expandable nerves or nerve fascicles to an injured more important nerve, distal to the site of injury (**Box 1**).

TIMING

The timing of the surgery should be carefully considered based on multiple factors including mechanism of injury, physical examination, and imaging results, as well as the surgeon's preference. Because of the degeneration of motor endplates that becomes mostly irreversible after approximately 12 to 18 months in adult patients, the observation period prior to surgery should be limited, and nerve transfers should be performed within 6 to 9 months after injury.[5,12,18,24–28] Some authors have expanded the time to surgery up to 12 months. Ideally, nerve surgery should be performed prior to 6 months when and if possible.

DESCRIPTION OF NERVE TRANSFER OPTIONS

For elbow flexion, the goal is to innervate the musculocutaneous nerve (MCN), or specifically the biceps (and/or brachialis) branch.[29] For elbow extension, either the whole radial nerve or branches to the long head of the triceps (BLHT) can be targeted.[30] Intraplexal donors are preferred when available.[31] Different nerve transfers may be combined to yield best functional outcome. In selecting the most appropriate donor, the number of motor axons, the distance between donor and recipient nerve and the size match with the recipient nerve should be considered. Different neurotization techniques for restoration of both elbow flexion and extension will be described in more detail.

Table 1
Indications and contraindications for nerve transfers

Indications	Contraindications
• Preganglionic injury (ie, nerve root avulsions) • High peripheral nerve injuries • Multiple level nerve injuries • Delayed presentation (between 6–12 mo) • Large neuromas in continuity • Innervation for free functioning muscle transfer	• Absolute contraindications ◦ Less invasive options possible ◦ Spontaneous recovery expected ◦ Irreversible damage of atrophy of recipient muscles (>12 mo from injury) ◦ Unmotivated patient for invasive procedure and intensive rehabilitation • Relative contraindications ◦ Joint stiffness and contractures, patient age, comorbidities, traumatic brain injury, or spinal cord injury