SCIENTIFIC ARTICLE

Submuscular Versus Subcutaneous Ulnar Nerve Transposition: A Cadaveric Model Evaluating Their Role in Primary Ulnar Nerve Repair at the Elbow

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Purpose To investigate the length gained from subcutaneous and submuscular transposition of the ulnar nerve at the elbow. Specifically, the study aimed to define an expected nerve gap able to be overcome, and to determine if a difference between transposition techniques exists.

Methods Eleven cadaveric specimens from the scapula to fingertip were procured. *In situ* decompression and mobilization of the ulnar nerve at the elbow followed by simulated laceration of the nerve was performed. Nerves were marked 5 mm from the laceration site to facilitate overlap measurement and to simulate nerve end preparation to viable fascicles before primary coaptation. Nerve ends were attached to spring gauges set at 100 g of tension (strain $\leq$ 10%). Measurements of nerve overlap were obtained in varying degrees of wrist (0°, 30°, 60°) and elbow (0°, 15°, 30°, 45°, 60°, 90°) flexion. Measurements were performed after *in situ* decompression and mobilization, and then repeated after both subcutaneous and submuscular transposition.

Results Ulnar nerve transposition was found to increase nerve overlap at an elbow flexion of 30° or greater. No difference was seen between subcutaneous and submuscular transpositions at all wrist and elbow positions. *In situ* decompression and mobilization alone provided an average of 3.5 cm of length gain with the elbow extended. Transposition in conjunction with clinically feasible wrist and elbow flexion (30° and 60°, respectively) provided 5.2 cm of length gain. Controlling for mobilization, a statistically significant increase in overlap of approximately 2 cm was gained from transposition.

Conclusions Although mobilization combined with wrist and elbow flexion may afford substantial gap reduction and should be used initially when approaching proximal ulnar nerve lacerations, transposition should be considered when faced with a large nerve gap greater than 3 cm at the elbow. No difference was seen between submuscular and subcutaneous transposition techniques.

Clinical relevance This study defines the extent an ulnar nerve gap at the elbow can be overcome by *in situ* mobilization, joint positioning, and transposition. It additionally compares the efficacy of submuscular and subcutaneous transposition techniques in closing this gap. *(J Hand Surg Am. 2017;■(■):1.e1-e7. Copyright © 2017 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Cadaver model, subcutaneous, submuscular, transposition, ulnar nerve repair.

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THE ULNAR NERVE LIES IN A SUPERFICIAL position at the level of the elbow and wrist, where it is most prone to injury.[1] Primary repair of ulnar nerve lacerations eliminates the need for nerve grafting, which has been shown to have worse outcomes than acute end-to-end repairs.[1–3] Anterior transposition of the ulnar nerve represents a relatively simple technique to gain additional length in cases where there may be a gap at the injury site.

Current and historical teachings emphasize the importance of anterior subcutaneous (SQ) transposition in this setting to gain length for primary nerve repair.[1,4–6] However, there is no agreement on the expected length gained from SQ transposition. Gap reduction cited in the literature ranges from 1 to 13 cm,[5–8] and the role of transposition for ulnar nerve lacerations about the elbow remains unclear.

The aim of this study was to quantify the length gained from SQ and submuscular (SM) transposition of the ulnar nerve at the elbow in a laceration model and to determine if the length gained from SM transposition differs from that gained from SQ transposition.

MATERIALS AND METHODS

Specimen selection and preparation

Twelve paired fresh-frozen entire upper extremities from the hand to the shoulder girdle including the scapula and glenohumeral joint were obtained through a standard specimen procurement process. One specimen was used for our pilot study, leaving 11 paired specimens for experimentation. Several exclusion criteria were used: prior operative intervention to the limb, history of nerve disorder to the involved limb, injectable drug abuse, prior trauma to the limb, congenital anomaly, and any disease process or cadaveric processing procedure that would limit shoulder, elbow, or wrist range of motion (ROM). Demographic information from each specimen was obtained including age at the time of death, handedness, medical and surgical history, smoking history, height and weight, and cause of death.

Specimens were warmed to room temperature. The glenohumeral joints were secured with a Steinmann pin and then the scapulae were secured to simulate typical operative positioning of the arm on the hand table during ulnar nerve exploration (Fig. 1). The ulnar length was measured from the tip of olecranon to ulnar styloid to the nearest millimeter for later data normalization of cadaver forearm length. Specimen wrist and elbow ROM was examined to ensure adequate ROM to obtain all measurements.

Experimental protocol and rationale

Exposure of the ulnar nerve was performed through a standard approach along a 15-cm curvilinear incision centered between the medial epicondyle and the olecranon process. A laceration of the ulnar nerve was created with a No. 10 scalpel blade 2 cm distal to the medial epicondyle, which was used as a bony landmark for reproducibility. Using a laceration located 2 cm distal to the medial epicondyle left the motor branch to the flexor digitorum profundus for the ring and little fingers, originating 3 cm distal to the medial epicondyle, attached to the distal nerve stump, and avoided its tethering of the proximal nerve stump during transposition.[1] The articular branch was sacrificed and neurolysis of the branches to the flexor carpi ulnaris was performed as indicated to achieve adequate transposition without tethering.

Nerve ends were then marked for later measurement with a epineural Prolene suture 5 mm proximal and distal to the laceration site to simulate clinical nerve end preparation during attempted repair. Nerve ends were then secured to commercial spring gauges using a 5-0 nylon suture (250 g spring gauge; Southern Science Supply, San Antonio, TX) to apply constant tension to the nerve. The spring gauge nerve end interface both proximally and distally was calibrated before each measurement to apply a 100 g tension to the nerve ends to simulate the surgeon pulling on each nerve stump to achieve primary nerve repair (Fig. 1).

To recreate the clinical scenario of a surgeon applying traction to a free nerve end to perform primary nerve repair without exceeding the strain threshold for vascular flow and neurorrhaphy integrity, a strain of 2% to 5% was selected. This correlated to the tension produced by 100 g of force applied to the free nerve ends according to previously published studies.[6] The choice of 100 g of tension in our study was multifactorial. Nerves possess *in situ* strain varying from approximately 2% to 11% in animal models, and this strain represents one of the reasons why they retract on laceration.[6] A tension of 5 N has been correlated to ischemia and decreased nerve function through the reduction in blood flow and conduction velocity.[6] Moreover, vessel occlusion occurs with strain between 8% and 15% and becomes irreversible in perineural vessels in animal studies at 15%.[9–11] As such, grafting (and thus abandonment of primary nerve repair) is indicated if tensionless repair is unachievable and if the nerve elongates by more than 10% of its original length with attempted end-to-end repair.[5] In our pilot study, using a technique commonly employed intraoperatively to ensure that