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# Submuscular Transposition of the Ulnar Nerve

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## Introduction

This chapter will delve into the surgical technique of submuscular transposition of the ulnar nerve. The chapter will cover the background of nerve transposition, the indications, described modifications of surgical technique, and outcomes. We will also cover in detail the authors' preferred surgical technique and postoperative care for submuscular transposition of the ulnar nerve.

## Background

Ulnar neuropathy describes a spectrum of pathology. Ulnar pathology can masquerade in various ways, with compression coming from the spinal column, thoracic outlet, elbow, or wrist. The etiology may be from bony or muscular compression, vascular disorder, or even be physiologic.

The ulnar nerve receives its innervation from cervical roots C8–T1 which coalesce to form the medial cord of the brachial plexus. The primary function of the nerve is to supply the critical sensation and fine motor functions at the most distal hand and digits. Pathology leads to clawing of the hand and atrophy of the intrinsic muscles. Few options exist for the end-stage disease, with tendon transfers being much less successful than those for pathology of the radial or median nerves. Therefore, it is imperative to treat the disease early to avoid the dreaded late outcomes.

As previously described in other chapters, there are many ways to surgically manage cubital tunnel. The nerve may be released in situ (also known as simple decompression) or be mobilized to another position, called transposition. Various means to transpose the nerve have been described including subcutaneous, subfascial, sub- or intramuscular. Medial epicondylectomy has also been described. The surgical approach to nerve decompression has always had supporters of various anatomic approaches by master surgeons, signifying that no consensus has been reached.

Stability of the ulnar nerve at the elbow is a key element in discussion of what to do with the nerve. Patients with evidence of nerve subluxation on preoperative exam may worsen if the nerve is not stabilized with some type of transposition or epicondylectomy. The same can be said for a nerve which preoperatively is stable at the elbow in flexion and extension but becomes unstable intraoperatively after surgical decompression. Many surgeons argue that an unstable ulnar nerve (noted either pre- or intraoperatively) should be transposed.

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Revision cubital tunnel surgery is discussed in further detail in following chapters. However, it warrants mention in this section given that many of authors recommend submuscular anterior transposition for cases of revision surgery to help decrease the risk of perineural scarring and adhesions [1, 2].

## History of Submuscular Transposition

The ulnar nerve courses posterior to the axis of rotation at the medial elbow putting it at risk of traction and compression with elbow flexion, potentially compromising its microcirculation; anterior transposition can eliminate these forces [3]. By moving the nerve to an anterior location, embedded within protective muscle, the local compressive and traction forces can theoretically be decreased. Advocates of transposition say that this addresses the dynamic compression of the nerve that occurs in elbow flexion [4, 5]. In submuscular transposition, the nerve is well protected and lies deep below substantial soft tissue [6]. Submuscular transposition lies close to the axis of motion and can eliminate iatrogenic-induced strain [7, 8]. The true submuscular pathway places the nerve directly over the elbow joint capsule which becomes the new bed in which the nerve lies [7].

The first description of the submuscular transposition was by Learmonth in 1942 [9]. This is what we now call anterior submuscular transposition (ASMT) of the ulnar nerve. Learmonth's technique was to detach the flexor-pronator mass from its insertion on the medial humeral epicondyle. The decompressed ulnar nerve was then transposed anteriorly and medially to the midline to lie next to the median nerve, coursing just over the smooth gliding surface of the anterior ulnohumeral joint capsule. The flexor-pronator mass was then reattached. Patients required postoperative splinting for several weeks with the elbow and the wrist flexed to ensure the musculotendinous insertion healed back to the epicondyle [10].

Dellon began using a modification of the Learmonth submuscular technique in 1980 and published his surgical technique several years later [10, 11]. This technique modification is referred to as a z-lengthening or V-Y advancement anterior submuscular transposition. Dellon's technique lengthens the flexor-pronator fascia to create space for the ulnar nerve in its transposed position while allowing repair of the flexor-pronator attachment without tension, all while allowing immediate flexion and extension of the elbow [10]. This modification is arguably the most common technique for ASMT currently. We refer the reader to a well-written surgical technique article by Dellon et al. in which they describe the V-Y submuscular lengthening in detail with clear intraoperative images and prudent surgical pearls [12].

A modification of the submuscular is intramuscular transposition, Adson is credited with first describing this in 1918 [13]. This modification consists of creating a trough in the flexor-pronator musculature in the projected line of pull of the nerve in its anterior transposed position [7, 14–17]. In this transposition, the flexor-pronator mass is *not* detached from the medial epicondyle. Proponents argue this allows earlier mobilization and less local trauma. Fascial flaps are raised, the muscular trough created, and the nerve is placed in its intramuscular position. Fascial flaps are repaired in a lengthened position to avoid undue tension on the nerve. This allows almost immediate mobilization of the wrist and elbow for early nerve gliding. A recent modification published by Henry merges the intramuscular and submuscular techniques and allows almost immediate motion for early nerve gliding [7].

Critics state that an intramuscular position may create a fibrotic scarring bed on the nerve that traps it and obstructs longitudinal nerve gliding [6]. However, work by Dellon et al. found no significant difference in nerve fibrosis, mean nerve fiber diameter, or percent of neural tissue when placing the ulnar nerve in a submuscular versus intramuscular position in a primate model [18].

In our review of the current literature, few current articles describe the intramuscular transposition which may hint that this technique has declined in popularity in relation to the modified submuscular transposition.

Several biomechanical and histologic studies have been published on ulnar nerve decompression and/or transposition. A biomechanical analysis using a micro-strain recording device found that 22 mm of ulnar nerve excursion is required at the elbow to prevent undue strain on the nerve [19]; any surgery aiming to mobilize the ulnar nerve at the elbow should aim to allow at least 2 cm of excursion.

Dellon et al. performed a cadaveric study to evaluate intraneural pressures following the common ulnar decompression techniques [20]. The authors found that ulnar nerve transposition and musculofascial lengthening reduced intraneural pressures both in elbow extension and flexion at 30°, 60°, and 90° by a minimum of 40% when compared to in situ decompression, medial epicondylectomy, subcutaneous transposition, and traditional Learmonth submuscular transposition.

A recent histologic study on a rat model showed healthier axons and less perineural scar tissue in rats treated with submuscular transposition compared to subcutaneous method [3].

Disadvantages of transposition include complexity of the procedure, extensive tissue dissection, risk of nerve devascularization, intraneural injury, perineural fibrosis, and chance of injury to the motor branch to the flexor carpi ulnaris (FCU) [21, 22]. Postoperative elbow immobilization may lead to contracture and prevent nerve gliding which can lead to adhesions.

## Comparative Trials

In the early 2000s, studies emerged pitting head-to-head simple decompression and transposition. Gervasio et al. performed a prospective randomized trial of 70 patients with either in situ or submuscular transposition and found no statistically significant difference in clinical or electrophysiologic outcomes [6]. Charles et al. published a retrospective review comparing in situ and submuscular transposition and found no significant difference in sensory or motor recovery in McGowan II and III patients [23]. They did find that patients with symptoms lasting longer than 6 months had a worse prognosis regardless of technique. Biggs et al. conducted a prospective randomized trial of 54 patients comparing in situ decompression and submuscular transposition; they noted equally effective neurologic improvement but higher wound complications in the submuscular technique [24].

Following the publication of these and other high-quality studies, systematic reviews and meta-analyses were able to be performed. A 2007 meta-analysis of four randomized controlled trials of simple decompression and anterior transposition found no difference in motor nerve-conduction velocities or clinical outcomes [25]. Chung performed a literature review in 2008 which showed that no single procedure had shown to be best. He concluded that based on review of the best available evidence, he had changed practice of using subcutaneous anterior transposition in favor of in situ release [26]. Published in 2008, Macadam et al. performed a meta-analysis of comparative trials or randomized controlled trials comparing in situ and transposition release. The authors found no statistically significant difference but a trend towards improved clinical outcomes with transposition as opposed to simple decompression [27].

Based on large national databases, it appears that the pendulum has shifted to favor simple decompression for primary nerve release. A 2013 study of the United States national ambulatory surgery data from 1996 to 2006 showed that transposition dropped from 49% to 38% in 2006, with women more likely to have simple decompression (70%) [28]. A more recent state-wide Florida database retrospective cross-sectional analysis for 2005–2012 showed that of over 26,000 cubital tunnel releases performed, 80% underwent had situ decompression, 16% underwent transposition, and 4% underwent “other” [29]. During the study period, there was a statistically significant increase in in situ release and decrease in transposition. Females and patients treated by high-volume surgeons had a statistically higher rate of in situ release. The published data did not state whether the data set could determine if release was primary or revision.

In a letter to the editor in response to results of the Charles et al. [23] study, MacKinnon eloquently described what appears to be the current approach to the ulnar nerve. MacKinnon argued that technical details of ulnar nerve surgery such as kinking of the ulnar nerve, appropriate decompression of the tendinous leading edge of the FCU, and respect for the medial brachial and antebrachial cutaneous nerves are likely more important than which procedure is done [30]. She also argued that simple decompression is likely to relieve symptoms in the majority of patients unless there is resultant subluxation of the nerve [30]. Charles et al. agreed but also noted that patients with major sensory or motor deficits or anatomic abnormalities around the epicondyle should be considered for transposition [23].

## Surgical Indications

Surgical decompression of the ulnar nerve at the elbow should only be performed after appropriate clinical workup.

A comprehensive physical exam is critical. The surgeon should document objective motor strength (grading M0–M5) and sensory discrimination with Semmes-Weinstein monofilament or two-point discrimination testing. Specific motor testing should include flexor digitorum profundus (FDP) to small finger, FCU, and first dorsal interossei. Specific sensory testing should document the palmar small and ring finger, dorsal ulnar hand (DSBUN) , and the medial distal arm (MBC) to rule out brachial plexus origin. The DSBUN and MBC can be graded using a 0–10 scale by the patient given that two-point and monofilament is difficult for the patient at these sites.

The absence or presence of ulnar pathologic signs should be described; these may include Wartenburg, Froment, Testut, first dorsal interosseous wasting, and clawing. The McGowan classification is unique for ulnar neuropathy and can be helpful to standardize the publication of results [31].

Appropriate workup with electromyography (EMG) and nerve conduction velocity (NCV) studies are usually indicated. This is helpful not only for staging the disease but also to monitor recovery or progression of pathology and is essential in the unfortunate event of medicolegal conditions.

The surgeon may want to send the patient through a dedicated course of physical and/or occupational therapy. Therapists work on scapular stabilization and nerve gliding for thoracic etiology [32, 33] and nerve gliding with dart throwers and FCU gliding for compression at the elbow [34, 35]. Nighttime splinting of the elbow in extension is also indicated in the nonoperative management of the disease [36, 37].

Once the appropriate workup and nonoperative course has been completed, surgery may be indicated. Surgical techniques vary widely and ultimately lie at the discretion of the treating surgeon. As described earlier, in situ decompression is usually sufficient for a primary cubital tunnel. For many surgeons, the current treatment algorithm begins with in situ release followed by subcutaneous or submuscular transposition if perching, subluxation, or dislocation is noted during surgery [38]; most surgeons regard ulnar nerve subluxation or dislocation as an indication for transposition [25]. Additionally, transposition may be indicated for a revision ulnar neurolysis at the elbow to help prevent scar formation [1, 2].

## Submuscular Transposition of the Author's Preferred Surgical Technique

Our current indication for the submuscular transposition is a patient with symptomatic ulnar nerve compression at the elbow. We prefer to obtain preoperative EMG and NCVs for all patients, as well as exhaust nonoperative measures including rest, nighttime splinting, physical therapy to include nerve gliding, and postural retraining. When these have failed, surgery is discussed with the patient.

In our experience, the majority of patients with primary cubital tunnel syndrome can be treated with simple decompression. Patients in whom we prefer to treat with transposition include those with evidence of nerve instability either pre- or intraoperatively. Additionally, we prefer this technique for revision decompression.

In a primary release, the surgical approach includes a curvilinear incision centered at the medial elbow in between the medial epicondyle and the olecranon (Fig. 15.1). Tourniquet is inflated and skin is incised. Dissection is taken down with the knife through skin only, followed by careful dissection with tenotomies paying close attention to identifying the MBC and MABC (Fig. 15.2). These are protected with vessiloops to prevent iatrogenic damage during surgery.

The nerve is then identified running posteriorly below Osborne's ligament (Fig. 15.3). The nerve is carefully decompressed proximally to the level of the triceps medial intramuscular septum at the middle to distal third of the humerus as the nerve crosses through the septum from anterior to posterior (Fig. 15.4). We prefer to excise the medial intermuscular septum at the distal third of the arm. Attention is taken to release the entire arcade of Struthers and carefully divide Osborne's arcuate ligament. Distally, the tendinous leading edge of the two heads of the FCU is divided (Fig. 15.5). Further, distal dissection ensures the nerve is released up to the fascial origin of the flexor digitorum superficialis to the ring finger.

Care is taken to perform external neurolysis so as not to unduly strip the nerve in order to preserve the vascular supply to the epineurium (Fig. 15.6). The above-described additional mobilization both proximal and distal is often required to allow the nerve to move anteriorly to its transposed position. The previous identification and protection of the MBC and MABC with vessiloops helps to speed this step. The nerve is then pulled anteriorly to check that appropriate mobilization has been completed.

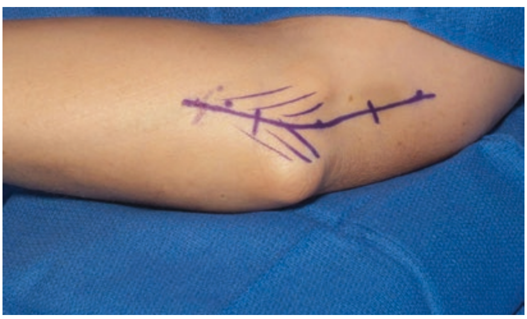

**Fig. 15.1** Typical surgical incision for submuscular transposition centered at the medial elbow halfway between the olecranon and medial epicondyle

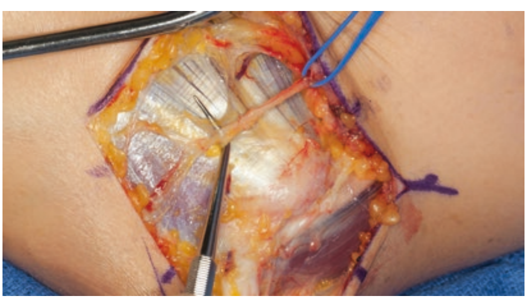

**Fig. 15.2** After skin dissection, the medial brachial cutaneous nerve is identified and protected

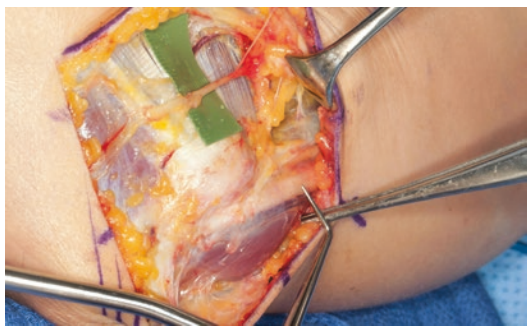

**Fig. 15.3** Before decompression, the ulnar nerve is seen running posterior to the epicondyle, in the figure the probe is pointing to the nerve

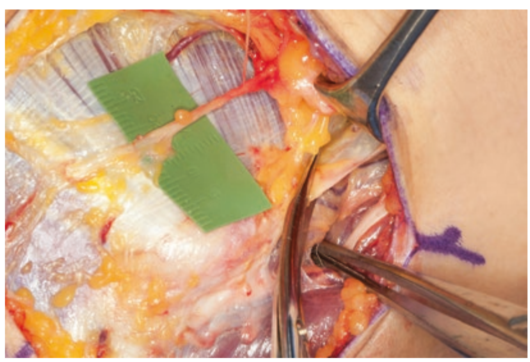

**Fig. 15.4** The triceps intermuscular septum is carefully identified and excised to relief proximal sites of compression and to avoiding a site for kinking of the nerve after transposition

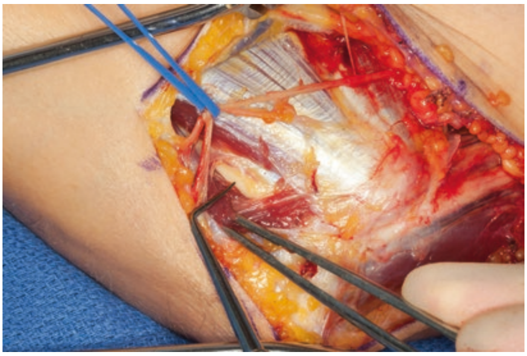

**Fig. 15.5** The ulnar nerve is identified distally in the wound where the heads of the flexor carpi ulnaris are decompressed

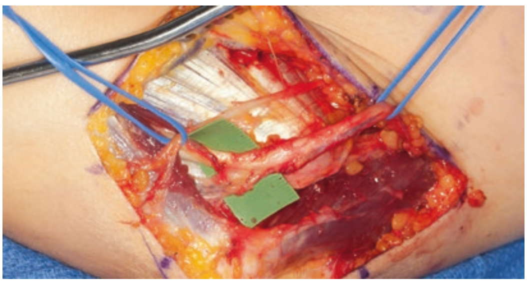

**Fig. 15.6** The ulnar nerve is now decompressed and carefully lifted using vessiloops. The medial brachial cutaneous nerve is also seen anteriorly in the wound, protected by vessiloops

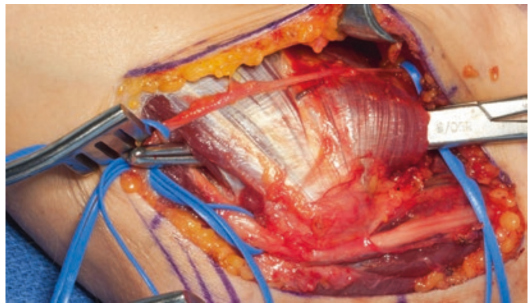

**Fig. 15.7** Using gentle submuscular blunt dissection, the flexor-pronator mass is identified

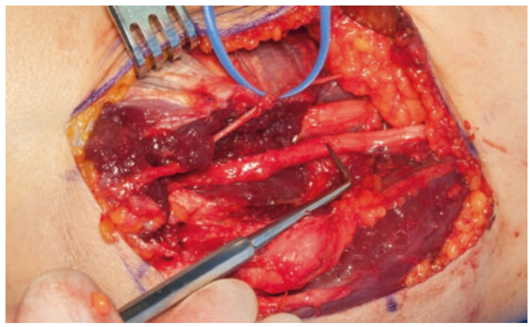

**Fig. 15.8** After detachment of the flexor-pronator mass from its insertion, the ulnar nerve is placed into its transposed position

Once the nerve is sufficiently decompressed and mobilized, attention is turned to the submuscular transposition. Gentle dissection just below the flexor-pronator mass allows the muscular mass to be elevated with the least amount of intramuscular bleeding (Fig. 15.7). The flexor-pronator mass is then detached from the epicondyle en bloc, leaving a small cuff of facial attachment for later repair. Care is taken to mobilize the flexor-pronator mass medially to ensure no undue tension on the nerve.

Fractional lengthening is performed. The most superficial fascia is divided fully which allows several millimeters of increased muscular excursion. Several distinct longitudinal septa are present which are divided to allow fractional musculotendinous lengthening. The most important of these is the ring finger flexor digitorum superficialis origin. If not released at its origin, it creates a hard edge that the nerve winds around when it lies in its transposed position. The septa can be released in two stages, first when the nerve remains in situ and second during this second look.

The nerve bed is then chosen. We have noted that a natural plane can usually be found that runs parallel to the nerve's native course. The muscle fibers in this plane are carefully mobilized to create a trough the nerve will lie in. The bed is checked carefully for any remaining fascial fibers from previously divided septa that might create kinking and lead to adhesions.

The nerve is then moved anteriorly into its new submuscular position, sitting on top of the anterior elbow joint capsule and within the new muscular trough created to form its new bed (Fig. 15.8). The flexor-pronator mass is then pulled over the ulnar nerve and sutured down in a slightly loosened manner to prevent undue ten-

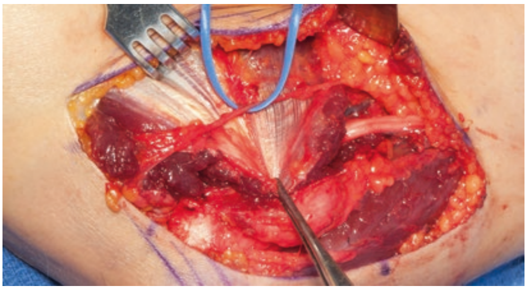

**Fig. 15.9** The flexor-pronator mass is gently reapproximated and the nerve is checked to be free without any undue tension prior to approximation. If tension is noted, additional musculofascial lengthening should be performed

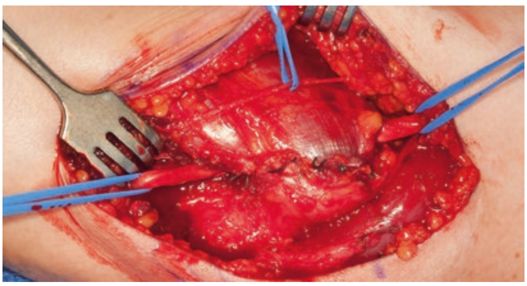

**Fig. 15.10** Flexor-pronator mass is reattached using nonabsorbable suture to protect the repair

sion on the nerve in its transposed position (Fig. 15.9). We prefer to use non-absorbable suture such as 2-0 fiberwire. The elbow is then ranged through extension and flexion to ensure no kinking or excessive force on the nerve in the transposed position (Fig. 15.10).

Tourniquet is deflated and meticulous hemostasis obtained to help prevent postoperative hematoma. We prefer to leave a deep drain which is removed on postoperative day 1. Skin is closed in layers with deep dermal 3-0 absorbable monofilament, followed by either running 3-0 subcuticular absorbable monofilament or interrupted 3-0 nonabsorbable monofilament suture. A bulky compressive dressing is applied followed by a long arm splint with the arm at 70–90° of elbow flexion.

Depending on the stability of the repair, range of motion is usually begun at 10–14 days postoperatively and the patient is allowed early nerve gliding to decrease risk of adhesions and perineural scarring. The patient will work on motion for up to 6 weeks post-surgery and thereafter may initiate strengthening. They are typically released to unrestricted activity at 3 months postop.

## Outcomes

Clinical outcomes are generally good for submuscular transposition. Dellon and Coert performed a prospective study of 161 extremities undergoing ASMT and found 88% good-excellent results at average follow-up of over 3.5 years [39]. Subgroup analysis found significant improvement among patient with diabetes, Workers' Compensation claim, and those with severe compression [39]. A study by Nouhan et al. found 97% good-excellent results [40], and Gervasio et al. noted 83% good-excellent outcomes [6]. Lee et al. performed a recent study of patients with severe disease undergoing V-Y lengthening ASMT; they noted 83% good-excellent results using a modified Bishop score [41]. Lee et al. noted a significant negative correlation between prolonged symptoms duration and modified Bishop score at final follow up, but age did not affect outcome [41].

Several studies have published objective results of nerve improvement. A prospective study of patients undergoing V-Y advancement ASMT found significant improvement in sensory and motor findings among all patients regardless of baseline nerve impairment [39]. A recent study of patients with severe disease (McGowan III) treated with submuscular transposition noted improvement of at least 1-McGowan grade in 94% of extremities [41]. Sixty-seven percent of patients had objective neurologic improvement in prospective randomized study in situ versus submuscular transposition [24].

The procedure is not without its complications. The incidence reported in the literature include symptomatic MABC neuroma requiring resection (1% [8] to 3% [39]), hematoma requiring drainage (0.5% [39]), reflex sympathetic dystrophy (1% [40]), and deep wound infection (1% [8] to 14% [24]).

Failure or recurrence rates with the submuscular technique vary. Dellon and Coert report 8% failure or recurrence [39] while Bacle et al. report a 7% recurrence rate [42]. A retrospective cohort study by Zhang et al. found secondary surgery rate of 11% for transposition compared to 2.5% for in situ release [8]. However, the results in Zhang et al.'s study may be skewed by selection bias given that patients undergoing transposition had higher McGowan grades and were more severe at baseline.

A recent systematic review by Macadam et al. showed that reliable, reproducible, and valid outcomes measures are lacking in the literature for cubital tunnel surgery [43]. The authors analyzed 42 studies and found 21 health outcomes measures, 2 generic instruments, 10 symptom-specific, author reported instruments; 3 symptom-specific, patient-reported instruments; and 6 patient questionnaires. Available data showed consistently high patient satisfaction after both simple decompression and submuscular transposition ranging from 65 to 92%, with no obvious association between author-reported and patient-reported results.

A multicenter group prospectively evaluated several outcome measures in patients undergoing simple decompression and found that the MHQ (Michigan Hand Questionnaire) and CTQ (Carpal Tunnel Questionnaire) are more responsive than DASH (Disabilities of the Arm, Shoulder and Hand) for ulnar neuropathy undergoing decompression [44]. These MHQ and CTQ questionnaires may be useful for detecting subtle outcomes differences in future studies of cubital tunnel decompression.

## Summary

Submuscular transposition of the ulnar nerve can be technically demanding but, when indicated, can provide satisfactory outcomes for patients. Our preferred indication is a patient with nerve subluxation or in the revision setting. A short course of postoperative immobilization followed by early guided therapy can help improve nerve gliding and decrease risk of adhesions.

Our current body of evidence does not support the use of transposition over in situ release for primary surgery. Many authors argue that submuscular or intramuscular transposition is warranted in patients with instability or subluxation of the ulnar nerve, anatomic variants precluding in situ release, or in the revision setting [1, 2, 23, 30]. Regardless of specific technique, it is essential to fully decompress the nerve in an extra-neural fashion, preserve extrinsic vasculature, pay careful attention to protecting crossing cutaneous nerves, and ensure after mobilization that no undue tension or mechanical block precludes effortless, tension-free nerve gliding for optimal ulnar nerve recovery.

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