Management of Iatrogenic Ulnar Nerve Transection

Mark Henry

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Abstract A case of iatrogenic ulnar nerve laceration at the elbow is presented. Five subsequent surgeries over the course of the ensuing 20 months were performed to address this complication. The article examines the scientific basis for the various decisions needed to formulate a strategy that effectively addresses the problem. Emphasis is placed on the microsurgery of nerve topics: direct nerve repair, autogenous cable nerve grafting, biodegradable conduits, decellularized nerve allograft, and transfer of the anterior interosseous nerve to the ulnar motor branch. The discussion covers the relationship between choices made at the level of the original injury at the cubital tunnel to the timing and selection of distal reconstructive efforts, with specific attention to the distinction between end-to-end anterior interosseous to ulnar motor branch transfer as opposed to the supercharged end-to-side variation of this procedure.

Keywords Grafting · Laceration · Nerve · Release · Ulnar

Case Report

A left hand dominant 51 year old male presented for initial evaluation of complete ulnar nerve motor and sensory deficits at 15 months after a previous surgical procedure of left carpal tunnel release and left cubital tunnel release. Pre-operative symptoms consisted of intermittent mild hand weakness and numbness involving the long, ring, and small fingers, left greater than right, for a period of 4 years. Three years previously, the patient had undergone anterior cervical decompression and fusion surgery. Pre-operative examination by the

hand surgeon was notable only for bilaterally negative Tinel's signs at the carpal tunnel and bilaterally positive Tinel's signs at the cubital tunnel. Initial management included counter-force bracing, outpatient therapy and bilateral injection into the flexor pronator muscle mass with a mixture of lidocaine and steroid. No effect was observed from these measures. Two months prior to his initial peripheral nerve surgery, the patient was evaluated by a neurologist. Nerve conduction study results are presented in Table 1. The neurologist's conclusions following history, physical examination, and ancillary testing were left ulnar neuropathy at the wrist (Guyon's canal) and C8 radiculopathy; mild denervation in the left abductor digiti minimi found on electromyography (EMG). The neurologist specifically stated in her conclusions that she could find no evidence for ulnar nerve entrapment at the elbow or median nerve involvement. With these findings, 7 weeks later, the patient underwent left carpal and cubital tunnel releases; no specific decompression was performed for Guyon's canal. The patient reported that he awoke in the recovery room with hand weakness and an ulnar nerve sensory territory that was completely anesthetic to touch. Three weeks later a second nerve study demonstrated a non-conductive ulnar nerve, and EMG revealed complete denervation. A month after the initial surgery, the patient was returned to the operating room (OR). The surgeon first explored Guyon's canal and reported normal findings, followed by exploration of the previous surgical site at the cubital tunnel, reporting transection of the ulnar nerve; a 6 mm Neurogen tube was cut in half and sutured to the ulnar nerve with 7–0 prolene. Three weeks later the patient was taken back to surgery and received an extensor carpi radialis brevis transfer to the thumb for adduction, and the long finger flexor digitorum profundus (FDP) was sewn side-to-side to the FDP tendons of ring and small. Eight months after the initial surgery, the patient was taken again to the OR to undergo an end-to-end (not supercharged end-to-side) anterior interosseous nerve (AIN) to ulnar motor branch transfer using

M. Henry (✉)
Hand and Wrist Center of Houston,
1200 Binz Street, 13th Floor, 77004 Houston, TX, USA
e-mail: mhenry@houstonhand.com

Table 1 Nerve conduction study results

	Right	Left
Median distal motor latency (msec)	3.4	3.4
Median distal sensory latency (msec)	2.8	2.6
Ulnar motor conduction velocity in forearm (M/sec)	54	55
Ulnar motor conduction velocity at cubital tunnel (M/sec)	58	55

7–0 nylon. Fourteen months after the initial surgery, the patient made his fifth trip to surgery and received an extensor carpi ulnaris tendon transfer to the FDP tendons of long, ring, and small. The author first encountered the patient after the fifth surgery.

After that initial encounter, the patient selected a course of hand therapy, including a lumbrical bar splint, the first he had ever received in the course of his ulnar palsy case. Upon reaching a clear plateau in therapy, he became very skilled at using the lumbrical bar, fully extending his proximal interphalangeal (PIP) joints with his extensor digitorum communis tendons. However, he continued to have severe, constant, and disabling pain emanating from the neuroma of his mixed ulnar nerve at the elbow surgical site. At 20 months from his initial surgery, the patient requested further surgery. He underwent resection of the ulnar neuroma at the elbow with cable nerve allograft reconstruction and metacarpophalangeal (MP) joint tenodeses to prevent full extension as a permanent internal replacement for the lumbrical bar splint. Allograft was chosen for the reconstruction to minimize donor site morbidity since there was zero potential for any motor recovery. The FDP tendons had already been transferred and the distal intrinsics already disconnected by the end-to-end AIN transfer. There was little potential for late sensory improvement, expected to reach protective sensation level at best, and thus the quality difference between auto graft and allograft was not likely to be noticeable. The primary purpose for reconstructing with any form of graft at all was to give the transected axons an effective pathway for regeneration to prevent recurrent neuroma formation. The patient stated that his pain level went to near zero from the moment he awoke in the recovery room and has remained that way since, constituting a dramatic change compared to his pre-operative state. His Disabilities of the Arm, Shoulder, and Hand score dropped acutely from 83 pre-operatively to 62 on his first post-operative visit. He now effectively extends his PIP joints and performs unassisted grasp and release with no further need for the lumbrical bar splint.

Discussion

Iatrogenic ulnar nerve laceration at the cubital tunnel is a devastating complication that requires a timely and

comprehensive response to optimize what will, at best, be a lifetime of permanently diminished function. As long as supple joint motion has been maintained, the well-known options for tendon transfer can be performed at any time following injury. Far more complex are the decisions regarding peripheral nerve microsurgery. Analyses of the specific topics relevant to this case follow.

Direct Nerve Repair vs. Autogenous Cable Grafting

The ideal response to sharp transection of a mixed nerve is immediate direct repair to capture the benefits of a single junction for regenerating axons to cross, vascularized nerve tissue on both sides of the junction, and minimal tension [1]. With immediate direct repair, 73 % of ulnar nerve lacerations recovered compared to 56 % that required cable nerve grafts [2]. Within days of injury, the transected nerve stumps retract, swell, and eventually fibrose, forming a neuroma proximally and a glioma distally. As these changes progressively occur, the nerve can eventually no longer be directly repaired without undue tension that causes excessive scarring at the junction, obstructing axonal regeneration. If the nerve cannot be repaired without undue tension, then reconstruction across the defect is needed. The best results have been observed with autogenous cable nerve grafts, recognizing the detracting features of: a segment of initially devascularized nerve that must then be revascularized by the surrounding wound bed, two junctions for axons to cross, and donor site morbidity [1–4]. The quality of ultimate motor recovery is a function of these variables, time between injury and surgery, age of the patient, medical co-morbidities, and the distance between the site of injury and the target muscles for re innervation [5]. Ulnar nerve laceration at the elbow denervates the hand intrinsics as well as the FDP and flexor carpi ulnaris in the proximal forearm. With the distances involved, and a rate of motor end plate loss of 1 % per week, the final intrinsic function of the hand is usually quite poor; only 57 % meaningful recovery with auto graft reconstructions coming from 30 years' experience [1]. In a series of 110 ulnar nerve lacerations, mostly at the forearm level, the 13 year follow-up demonstrated meaningful recovery in only 51.8 % [4]. Meta-analysis of 33 studies identified a meaningful ulnar motor recovery rate of 58.8 % [6]. However, the extrinsic motors are much closer and constitute a solid reason to pursue early nerve reconstruction, along with the eventual recovery of protective sensation to the ulnar hand. Sensory end organs are not permanently lost to the same degree as motor end plates where useful sensory recovery has been demonstrated in 68 % of proximal ulnar nerve injuries [6].

The Role of Biodegradable Conduits and Decellularized Allograft

In recognition of the donor site morbidity and limited supply of autogenous nerve grafts, conduits have been in use for several decades [7]. Most commonly employed for digital nerve sensory reconstruction over short distances (35 % quantitative improvement, 45 % qualitative improvement) conduits have also been used more proximally to reconstruct mixed nerves [8]. Although collagen conduits have demonstrated good results when used to repair mixed median nerves without defects, cumulative data does not support their use for reconstruction of motor function across larger defects [9–12]. If the target muscle groups are considered important for function and no absolute contraindication exists, then autogenous cable nerve grafting is preferable to a conduit for mixed nerve reconstruction proximal to the wrist.

A more recent alternative for reconstructing nerve defects is decellularized nerve allograft. The allograft nerves are technically inset like autogenous cable nerve grafts. Recent data indicates that motor regeneration is superior to conduits but inferior to autogenous grafts [10, 12–15]. Only 1 in 12 conduits achieved meaningful recovery for mixed nerves with less than 25 mm defects [16]. Allografts perform closer to the standard of auto grafts for sensory recovery than motor recovery [10]. The multicenter RANGER study on decellularized allografts reported sensory recovery of S3 or better in 85 % of cases, with a mean moving and static two point discrimination of 8 mm [17]. Subgroup analysis demonstrated meaningful mixed function recovery (S3 or better sensory, M3 or better motor) for 67 % of ulnar nerve reconstructions [17]. When reconstructing a non-critical function, or under already highly compromised circumstances, the absence of donor site morbidity may outweigh the inferior regeneration of allografts compared to auto grafts. If a critical motor function is the target of re innervation, autogenous cable grafting remains the preferred strategy.

The Role of AIN to Ulnar Motor Branch Nerve Transfer

The long distance from the elbow to the hand intrinsic muscles ensures that the arrival of regenerating axons will be substantially delayed no matter how soon following injury the proximal nerve microsurgery is performed. To provide innervation to the intrinsic muscles of the hand and forestall additional motor end plate loss, a closer source of motor axons has value. Transfer of the AIN to the ulnar motor branch has been developed to provide such a source of motor axons [18–21]. Two versions of the procedure exist, end-to-end and supercharged end-to-side. End-to-end transfer precludes any recovery from proximal nerve microsurgery and is chosen when the surgeon calculates that the potential for intrinsic recovery from proximal axons is minimal to none [19]. If

proximal nerve microsurgery has been performed, and some degree of meaningful recovery is anticipated, then supercharged end-to-side is chosen. In this version, the distal end of the AIN is transferred into a perineurial window in the side of the ulnar motor branch, 8–9 cm proximal to the wrist. Axons regenerate from the AIN to reach hand intrinsic muscle targets and halt further losses of motor end plates. But, since the continuity of the ulnar motor branch has not been interrupted, subsequent arrival of regenerating axons from the proximal ulnar nerve can still re innervate hand intrinsics, linking the muscles to their original locus of cortical control [18]. Regardless of which version of AIN transfer is chosen, the timing for the nerve transfer is as soon as the patient encounters a micro surgeon capable of performing the procedure, if the procedure is to be performed at all. Observations of electrical activity on nerve conduction and electromyography midway during recovery are not able to predict functional outcome and cannot be used as an indication for selecting reconstructive strategies. A recent study demonstrated that even the final electrical study results have no correlation with functional outcome [22]. There is no basis for intentionally delaying a procedure whose success is dependent on time-sensitive axonal regeneration to re innervate distal motor targets that are progressively losing motor end plates.

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