Reconstruction of high ulnar nerve lesions by distal double neurotization using motor and sensory branches from the median nerve

Ahmed Semaya

Department of Orthopaedics and Traumatology, El-Hadra University Hospital, Alexandria School of Medicine, Alexandria University, Alexandria, Egypt

Correspondence to A.E. Semaya, MD, Department of Orthopaedics and Traumatology, El-Hadra University Hospital, Alexandria School of Medicine, Alexandria University, Alexandria, Egypt
Tel/fax: +20 359 130 30;
e-mail: semayamicro71@yahoo.com

Received 11 May 2015
Accepted 21 May 2015

Egyptian Orthopedic Journal 2015, 50:122–126

Background
High ulnar nerve lesions often have a poor prognosis as a result of the long distance between the site of injury and the innervated intrinsic muscles of the hand. Even with the most meticulous microsurgical repair, some cross innervations show poor recovery.
Patients and methods
There were four patients with irreparable high ulnar nerve lesion, three men and one woman. The mean age of the patients at surgery was 24 years (range from 17 to 38 years). The mean time from injury to surgery was 3.3 months (range from 2.5 to 5 months). Reconstruction of irreparable high ulnar nerve lesion was performed by transfer of two terminal branches from the median nerve, the anterior interosseous nerve supplying pronator quadratus muscle and palmar cutaneous branch, to the motor and sensory branches of the ulnar nerve at the level of the wrist. The mean postoperative follow-up duration was 22 months (range from 12 to 38 months).
Results
Results were graded using the Highet-Zachary scale. Good motor and sensory recovery was observed in three cases. The remaining case had only a protective sensation and required a secondary tendon transfer. No functional deficit in pronation occurred.
Conclusion
Although the number of patients in our report is small, the procedure provides a good option to restore the ulnar nerve functions in cases of irreparable high ulnar nerve lesion. The procedure is easy to perform, with minimal donor-site morbidity.

Keywords:
anterior interosseous nerve, high ulnar nerve lesion, neurotization, palmar cutaneous nerve of median nerve

Egypt Orthop J 50:122–126

1110-1148

Introduction

High ulnar nerve lesions often have a poor prognosis because the ulnar nerve is a mixed nerve that carries both sensory and motor fibers and even with the most meticulous microsurgical repair, some cross innervations show poor recovery. Also, the long distance between the site of lesion and the innervated intrinsic muscles of the hand made it take long time to reach the motor end plate. During this period, the denervated intrinsic muscles will undergo irreversible atrophic changes. Sensory recovery occurs in most cases with different degrees because the sensory nerve endings can tolerate long durations of denervation [1–5].

Ulnar nerve lesion causes partial clawing and weak hand grip and pinch. This cannot be corrected fully by tendon transfers. There are many techniques to restore the motor and sensory function of irreparable high ulnar nerve lesion by distal nerve transfer from the median nerve at the level of the wrist and hand [6]. The aim of this report is to describe the surgical technique and report the results obtained with reconstruction of irreparable high ulnar nerve lesion by transfer of two terminal branches from the median nerve, the anterior interosseous nerve (AIN) supplying pronator quadratus muscle and palmar cutaneous branch, to the motor and sensory branches of the ulnar nerve at the level of the wrist.

Patients and methods

This report included four patients with high ulnar nerve lesion. They were operated upon between December 2005 and March 2008. They were referred to our institution for secondary reconstruction. The first patient had a gunshot injury at the axilla that resulted in axillary artery and ulnar nerve injuries. He was managed by axillary artery reconstruction using a saphenous vein graft and no ulnar nerve repair was performed. There was a high risk to exploration of the ulnar nerve in this patient because of massive scarring at the axilla. In the second and third patients, there was high ulnar nerve injury associated with skin loss in the arm because of a road traffic accident in the second and

a machine injury in the third. Both patients required several procedures of debridement and skin grafting, and no primary ulnar nerve repair was performed. The fourth patient had an ulnar nerve injury at the elbow that was managed by sural nerve grafting. He presented with a painful neuroma that interfered with daily living activities without recovery of ulnar nerve functions. In the second, third, and fourth patients, exploration of the ulnar nerve was performed and the neuroma was excised, resulting in a long defect of the ulnar nerve (an average of 12 cm). This long defect of the ulnar nerve required a long sural nerve graft with a poor prognosis. Therefore, nerve grafting of the ulnar nerve was not performed in these cases and we proceeded to distal nerve transfer from the median nerve at the level of the wrist in the same setting. An informed written consent was obtained from every patient. This report was approved by the institutional review board (IRB).

The mean age of the patients at surgery was 24 years (range from 17 to 38 years). There were three men and one woman. The mean duration from injury to surgery was 3.3 months (range from 2.5 to 5 months) (Table 1).

Before surgery, all patients had complete ulnar nerve palsy (M0, S0, and positive Froment's sign). Preoperative electrodiagnosis electromyography was performed for all patients and no contractile muscle fibers could be detected.

Surgical technique

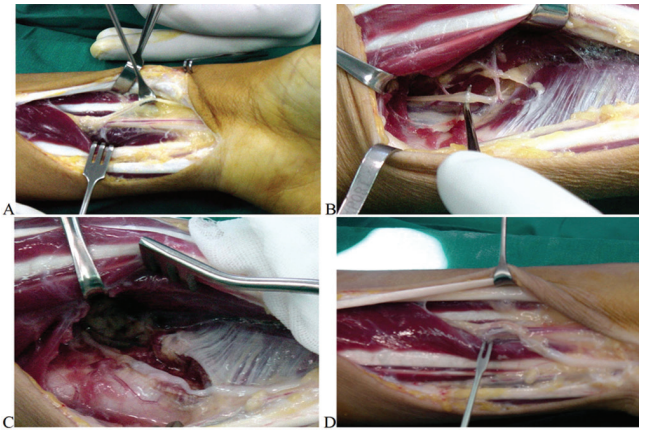
The procedure was performed under general anesthesia with a tourniquet. The surgical approach started at the pisiform and extended proximally in a lazy S shape. The palmar cutaneous branch of the median nerve was identified about 5 cm proximal to wrist crease. The terminal branch of the AIN supplying the pronator quadratus muscle was indentified at the proximal border of the muscle. The motor and sensory branches of the ulnar nerve were identified by interfascicular dissection using the dorsal cutaneous branch of the ulnar nerve as a guide. The palmar cutaneous branch of the median nerve was sutured to the sensory branch of the ulnar nerve. The motor branch of pronator quadrates was sutured to the motor branch of the ulnar nerve. An epineural suture under the microscope was made using 10-0 nonabsorbable stitches (Fig. 1).

Postoperatively, the wrist was immobilized for 3 weeks. A rehabilitation program was started immediately after this period.

The motor recovery was assessed using the British Medical Research Council grading system. The muscle functions that were assessed were finger adduction and abduction and isolated adduction and abduction of the little finger. Froment's sign was used to assess the adduction of the thumb. Also, the grip and pinch strength was measured using a dynamometer and compared with the normal side. Sensory recovery was assessed in terms of pain, touch, and static and moving two-point discrimination [7].

The final results of motor and sensory recovery were graded using the Highet-Zachary scheme (excellent: M5, S4, negative Froment's sign; good: M3 or M4, S3+, negative Froment's sign; or poor: M2 or less, S3 or less, positive Froment's sign).

Figure 1



Operative technique. (a) The palmar cutaneous branch of the median nerve was identified. (b) The motor branch of the pronator quadrates muscle was identified at the upper border of the muscle. (c) Microsurgical neurorrhaphy of the motor branch of the pronator quadrates muscle to the motor branch of the ulnar nerve. (d) Microsurgical neurorrhaphy of the palmar cutaneous branch of the median nerve to the sensory branch of the ulnar nerve.

Table 1 Preoperative and postoperative data of the patients

Patient	Age (years)	Sex	Mechanism of injury	Level of injury	Time from injury to surgery (months)	Postoperative follow-up period	Postoperative motor grade	Postoperative sensory recovery	Froment's sign	Two-point discrimination (mm)	
										Static	Moving
1	17	Male	Gunshot	Axilla	2.5	38	M4	S3+	—	6	5
2	38	Male	Road traffic accident	Midarm	5	22	M1	S2	+	—	—
3	22	Female	Machine	Midarm	3	16	M4	S3+	—	8	7
4	19	Male	Road traffic accident	Elbow	2.5	12	M3	S3+	—	7	6

–, negative; +, positive.

Results

The mean postoperative follow-up period was 22 months (range from 12 to 38 months). At the final follow-up, three patients showed good results according to the Highet-Zachary scheme (M3 or M4, S3+, and negative Froment's sign). The first dorsal interosseous muscle was recovered (M3) in one patient and (M4) in the other two patients. The fourth patient showed a poor result (M1, S2, positive Froment's sign).

In patients with good results, the average static two-point discrimination was 7 mm (range from 6 to 8 mm) and the moving two-point discrimination was 6 mm (range from 5 to 6 mm). The grip and pinch strength in patients with good results was 80% of the normal side. The partial clawing was corrected in these patients. The muscle wasting was not fully restored (Fig. 2).

The patient with a poor result had some touch sensibility and no two-point discrimination could be detected. The grip and pinch strength in this patient was only 40% of the normal side. The partial clawing was not corrected and the patient needed tendon transfer using the flexor digitorum superficialis of the ring finger.

No functional deficit in pronation occurred in any patient. All patients had no complaints as in terms of the anesthetic area supplied by the palmar cutaneous branch of the median nerve. No painful neuroma was reported in the distal forearm, where the two terminal branches of the ulnar nerve were cut.

Figure 2

Male patient, 22 years old, was involved in a road traffic accident. He presented 2.5 months later with a high ulnar nerve lesion and massive scaring at the axilla after axillary artery reconstruction with a saphenous vein graft. (a, b) Preoperative photos of patient show partial clawing, muscle wasting, and weak abduction compared with the other side. (c) Postoperative photo of the patient shows correction of the partial clawing and good abduction, although the muscle wasting was not fully restored.

Discussion

There are many series reporting that high ulnar nerve lesions above the level of the elbow often have a poor prognosis. This is attributed to the fact that the ulnar nerve is a mixed nerve that carries both sensory and motor fibers and even with the most meticulous repair under the microscope, some cross innervations show poor sensory and motor recovery. Also, the long distance between the site of lesion and the innervated intrinsic muscles of the hand made it take long time to reach the motor end plate. During this long period, the denervated intrinsic muscles will undergo irreversible atrophic changes.

Gaul [1] reported that adults with high ulnar nerve lesions never recovered acceptable function. Vastamäki *et al.* [2] concluded that a satisfactory result cannot be expected if the level of injury is more than 60 cm from the tip of the middle finger (i.e. high ulnar nerve lesions). Taha and Taha [3] reported that tendon transfer was needed in 72% of patients with high ulnar nerve lesions. Ruijs *et al.* [4] reported the meta-analysis of 23 articles including the individual data for 623 median or ulnar nerve injuries. In ulnar nerve injuries, the chance of motor recovery was 71% lower than that in median nerve injuries. Secer *et al.* [5] reviewed the results of repair of ulnar nerve lesion caused by gunshots in 455 patients over 40 years. Good results were noted in 15.06% of patients who had high-level lesions, 29.60% of patients with intermediate-level lesions, and 49.68% of patients with low-level lesions. Pfaeffle *et al.* [8] observed that all patients with high-level ulnar nerve lesions required tendon transfer because the motor recovery is usually poor.

In this report, the terminal branch of the AIN supplying pronator quadrates muscle was transferred to the motor branch of the ulnar nerve. From the anatomical point of view, the width and the number of myelinated fibers of both nerves are similar (the pronator quadratus branch of the median nerve was 1.5 ± 0.4 mm in diameter, with 866 ± 144 nerve fibers). The deep branch of ulnar nerve was 2.1 ± 0.4 mm in diameter, with 1318 ± 120 nerve fibers [9–11]. Direct coaptation is performed without the need for nerve grafting. The functional loss is minimal after denervation of pronator quadrates as the pronator teres can compensate. All of these advantages make this procedure a good option to restore the motor function of irreparable high ulnar nerve lesions.

In this report, good motor recovery (M3 or M4) was observed in three out of four patients. The first dorsal interosseous muscle recovered (M3) in one patient and (M4) in the other two patients. This resulted in good postoperative lateral pinch and grip strength. The fourth patient had poor motor recovery (M1) and tendon

transfer was needed to restore the motor function. Novak and Mackinnon [12] managed high ulnar nerve injuries in eight patients by distal nerve transfer of the AIN to the deep motor branch of the ulnar nerve, and no sensory nerve transfer was performed to the sensory branch of the ulnar nerve. They showed that all the eight patients had reinnervation of the ulnar nerve intrinsic hand muscles, with improved postoperative lateral pinch and grip strength. One patient had a secondary tendon transfer. The first dorsal interosseous muscle was not recovered often in their series. Sensory recovery of the ulnar nerve in these cases was because of proximal repair of the ulnar nerve injuries. Haase and Chung [13] managed two cases with high ulnar nerve injuries by distal nerve transfer of the AIN to the deep motor branch of the ulnar nerve. They reported return of function to the ulnar-innervated intrinsic muscles of the hand in these two cases. Protective sensation was restored through the native pathway of the ulnar nerve after proximal repair of ulnar nerve injuries. Wang and Zhu [14] reported that transfer of the pronator quadratus branch of the AIN to the recurrent branch of the median nerve and the deep branch of the ulnar nerve to restore the intrinsic functions of the hand was performed on 20 patients. Fourteen patients were followed up for an average of 68 months. In the latest follow-up, normal muscle strength (M5) was regained in three patients, M4 strength in six patients, M3 strength in three patients, and M2 strength in two patients. No sensory nerve transfer was performed in these cases. Battiston and Lanzetta [15] treated seven patients with high ulnar nerve lesions by distal nerve transfer of the AIN and palmar cutaneous branch of the median nerve to the motor and sensory branches of the ulnar nerve at the wrist. They reported good motor recovery (M3 or M4) in six out of seven cases and all of them achieved S3+.

There are many options to restore the sensory function of high ulnar nerve injuries by distal nerve transfer from the median nerve or by end-to-side repair to the median nerve. In our report, the palmar cutaneous branch of the median nerve was transferred to the sensory branch of the ulnar nerve. Three patients showed good results (S3+). The fourth patient showed a poor result (S2). These results were similar to those obtained by Battiston and Lanzetta [15] using the same technique.

Ozkan *et al.* [16] described end-to-end transfer of the ulnar digital nerve of the index or long finger to the ulnar digital nerve of the small finger. They reported good sensory recovery in most cases. The disadvantage of this technique is that it decreased the sensory area in the same hand. Brown *et al.* [6] described end-to-end transfer of the third common palmar digital nerve of median nerve to the volar sensory component of ulnar nerve and end-to-side reinnervation of the ulnar dorsal cutaneous branch to the remaining median sensory trunk. The sensory recovery was acceptable in their work. Many authors described end-to-side suture of the sensory ulnar nerve component to the third common palmar digital nerve of the median nerve in the palm or to the trunk of the median nerve in the distal forearm with variable results. The advantage of this technique is that no additional sensory loss occurred [17–20]. In our report, all patients had no complaints in terms of the anesthetic area supplied by the palmar cutaneous branch of the median nerve, which makes it a good option to restore sensation in high ulnar nerve lesions.

To our knowledge, only a few publications have used the same technique of distal double neurotization of high ulnar nerve lesions using the AIN and the palmar cutaneous nerve of the median nerve to restore the motor and sensory function of the ulnar nerve. This report clarified the indications, the advantages, and disadvantages, and showed satisfactory results.

Conclusion

Although the number of patients in our report is small, the procedure provides a good option to restore the ulnar nerve functions in cases of irreparable high ulnar nerve lesions. The procedure is easy to perform, with minimal donor-site morbidity.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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