Zagazig University Medical Journal
www.zumj.journals.ekb.eg

July.2021 Volume 27 Issue 4

Manuscript ID ZUMJ-1907-1385 (R1)

DOI 10.21608/zumj.2019.15527.1385

ORIGINAL ARTICLE

Early Neurotization of High Ulnar Nerve Injury Using Anetrior Inter-osseous Nerve for Restoration of Intrinsic Muscles Function

Raafat Abd Ellatif Anani [1], Mohammed Abbas Hegazy Elwahsh [2], Ayman Fikry Mehanna [3], Sameh Sabry Mohammad Hasan [4]

1 Faculty of Medicine, Zagazig University, Department of plastic Surgery, Sharkia Egypt
2 Faculty of Medicine, Zagazig University, Department of plastic Surgery, Sharkia Egypt
3 Faculty of Medicine, Zagazig University, Department of plastic Surgery, Sharkia Egypt
4 Alahrar teatching hospital,Department of Plastic Surgery,Sharkia Egypt

Corresponding author
Sameh Sabry Mohammad Hasan
Alahrar teatching hospital,Department of Plastic Surgery,Sharkia Egypt

dr.sameh.2011.187@gmail.com

Submit Date 2019-08-05
Revise Date 2019-08-26
Accept Date 2019-09-15

ABSTRACT

Back ground: Nerve transfer surgery, also known as neurotization, developed in the mid- 1800s with the use of animal models, and was used in the treatment of brachial plexus injuries. Neurotization relies on the fact that high ulnar nerve lesions usually have a poor prognosis because of the long distance between the site of injury and the targeted intrinsic muscles of the hand. Expendable motor or sensory nerves can be re-directed in proximity of a specific target, whether a muscle or skin territory, in order to obtain faster re-innervation. **Aim of the work:** was to evaluate the outcome and functional results of early neurotization of high ulnar nerve injury. **Methods:** A total of 12 patients, 9 males and 3 females were included in this study and underwent neurotization of high ulnar nerve injury using anterior interosseous nerve transfer to deep motor branch of ulnar nerve at Plastic Surgery Unit, faculty of medicine, Zagazig university hospitals in the period from 12/2017 to 2/2019. **Results:** nerve transfer provides satisfactory regaining of function in small muscles of hand and prevent permanent handicapping of the affected hand. **Conclusion:** Neurotization of high ulnar nerve injuries is a simple procedure that provides a good option to restore the ulnar nerve functions in cases of high ulnar nerve lesions. The procedure is easy to perform, with minimal donor-site morbidity.

Keywords: Nerve transfer, High ulnar nerve injury, anterior interosseous nerve.

INTRODUCTION

Ulnar nerve injuries result in loss of both the sensory and motor elements within the hand. these injuries can be classified by the site of injury into low injuries and high injuries. In low ulnar nerve injuries, the nerve is injured distal to the motor branch of the Flexor carpi ulnaris (FCU) and motor branch to the Flexor digitorum profundus (FDP) of the ring and little fingers. In low injuries, sensation is lost in palmar ulnar hand and paralysis occurs usually to all 7 interossei, the ulnar 2 lumbrical, the 3 hypothenar, the adductor pollicis, and the deep head of the flexor pollicis brevis muscles [1].

While high-level injuries lead to the loss of both grip and pinch strength in the hand, and sensation in the little finger and the ulnar side of the ring finger. In such injuries, the nerve is injured above the origin of the motor branch of the FCU and FDP muscles [2].

The loss of function of small muscles of the hand results in an inability to flex at the metacarpo-phalangeal (MCP) joints and extend the interphalangeal (IP) joints. This results in the development of the deformity described as claw posture of the ring and little fingers, where there is hyperextension at the

MCP joints and flexion at the IP joints (Duchenne's sign) [3].

After peripheral nerve lesion axonal regeneration is at a rate of 1-2 mm/day. Because muscle fibers undergo irreversible changes after 12 months of denervation, it is important that treatment be undertaken as early as possible for successful functional recovery [4].

Very high lesions in the arm, even when treated within 3 months following injury, carry a high risk of undergoing irreversible muscle changes before the regenerating nerve can reach the motor end plates of targeted muscles [5].

Nerve transfer for high ulnar nerve injuries described as transfer of Anterior interosseous nerve (AIN) to deep branch of ulnar nerve to restore motor function either original end to end or more recently "supercharged end-to-side nerve transfers" (SETS) as termed by Mackinnon and colleagues when primay repair has been done at time of injury [5].

In the forearm, the topography of the ulnar nerve is sensory-motor-sensory from lateral to medial. That is, the sensory fascicular group that supplies the palmar side of the fourth and fifth digits is found on the lateral side of the ulnar nerve. Another fascicular group, which represents the deep motor branch of the ulnar nerve, lies just medial to the sensory component between it and the dorsal cutaneous branch that lies on the ulnar side of ulnar nerve [6].

AIM OF THE WORK

To evaluate the outcome and functional results of early neurotization of high ulnar nerve injury.

PATIENTS AND METHODS

This study has been conducted at the plastic & micro-surgery department, faculty of medicine, Zagazig university hospitals. 12 patients, 9 males and 3 females with a mean age of 28.5±6.86 ranging from 18 to 42 years old were included in this study. The mean time interval before surgery was 4.25±1.48 with minimum 2 months and maximum 6 months. All patients suffered from proximal high ulnar nerve injury and were included for distal neurotization. All patients had been submitted to 1ry repair of ulnar nerve at time of trauma. The study was approved by the institutional review board (IRB). Informed consent to participate was obtained from each subject. The work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Inclusion criteria:

To be included in the study, the patient must fulfill all the following criteria:

1. Site of the injury: at or above level of elbow and proximal to FCU branch origin.
2. Nature of the injury; post traumatic injury.
3. Sex; both males and females.
4. Age; any age.
5. Time of presentation of injury: before 6 months of injury.

Exclusion criteria:

The patients with any of the following criteria were excluded from the study:

1. Any patient with non-post traumatic injury either inflammatory or tumor caused palsy or idiopathic.
2. Any distal injury below origin of FCU branch.
3. Any other concomitant distal injury of the nerve in the wrist or fractures.
4. Delayed presentation after 6 months of injury.
5. Any patient refusing participation in this study.

Study design:

- **Preoperative Management and Evaluation:**

- Evaluation of the affected limb:

Examination of the intrinsic muscles of affected limb was done to all patients as follows:

1- Examination by card test to test adductor pollicis muscle.
2- Examination of abduction to test palmar inter-osseii.
3- Examination of adduction of fingers to test dorsal inter-osseii.
4- Examination of flexion of MCP joint to test lumbricals.

Froment's sign was found + in all patients. No active range of motion and no palpable muscle contraction was found in all patients

for abduction and adduction for fingers and flexion of MCP joints grade 0 on modified MRC grading.

- *Investigations:*

▪ *Radiological:*

- *Plain X-ray was done for all patients on the affected limb.*
- *EMG and nerve conduction velocity was done for the affected limb for ulnar nerve supplied muscles.*
- Superficial U/S was done on ulnar nerve to ensure complete tear of nerve.

Steps of action and techniques used:

- **Pre-operative preparation:**

1) Accurate recording of pre-existing muscle power, range of motion of joints was done.

2) Clarifying of realistic goals before the surgery, including risks related to possible donor morbidity (transient and permanent) and slow nature of recovery.

3) Administration of preoperative anti-biotic within 1 hour before surgery>

4) Positioning and Anesthesia:

a. Patients were operated on under general anesthesia.

b. The arm was placed in an abducted position on table to enhance the exposure [7].

- **Surgical technique:**

The procedure was begun after application of tourniquet by decompressing the ulnar nerve throughout the Guyon canal. A simple 5- step maneuver was used to identify and decompress the deep motor branch of the ulnar nerve:

1) Opening Guyon canal:

A. A Taleisnik incision was made 6–7 mm to the ulnar side of the theanar crease or the radial axis of the fourth digit.

B. The incision then extended across the wrist in a zigzag manner.

C. If the palmaris brevis muscle was found after the release of the palmar fascia, this was divided.

D. Fascial bands that compress the ulnar nerve were released.

2) The neurovascular bundle was swept medially by a hanging loop to provide exposure of the ulnar nerve branches.

3) The hook of the hamate was felt. This is where the deep motor branch turns radially around the hook and dorsally under the hypothenar muscles.

4) The muscle fascia of the hypothenar eminence was identified & followed proximally until the leading edge of the hypothenar muscle fascia was encountered.

5) The deep motor branch was decompressed under the leading edge, around the hook of hamate, to the flexor tendon of the fifth digit [6].

Next the incision was extended proximally and the ulnar nerve was tracked into the forearm until the origin of dorsal cutaneous branch of the ulnar nerve.

It was easy to locate the dissection plane between the motor fascicles and the ulnar sensory fascicles in the forearm, by taking a small pair of micro pick- ups and gently tapping across the transverse diameter of the ulnar nerve. With this maneuver, the micro-forceps will slide into the division plane between these fascicular groups; sensory is lateral and the motor group is on the ulnar side. Once this plane has been located, intra-neural dissection was performed for several centimeters and the motor branch was hanged by a loop [6].

In the mid-portion of the forearm the anterior interosseous nerve was found with the vessel entering the pronator quadratus muscle. The pronator quadratus muscle was identified by taking away all of the flexor tendons radially with retractors. In proximal and central part of the pronator quadratus the neurovascular bundle was seen entering the muscle. Then separation of the nerve from this bundle and following it into the muscle was done to gain several centimeters in length. It was divided at this point and put so that it could be sutured to the deep branch of ulnar nerve.

Then anastomosis between AIN and deep branch of ulnar nerve was done using 9/0 nylon and application of fibrin glue.

Suturing of the wound was done and application of a soft drain at site away from repair site the dressing and splinting the hand and forearm in a dorsal splint with the wrist immobilized in 20 degrees of flexion was done

- **Post-Operative Measures:**

After the operation, the wrist is immobilized in a splint in 20 degree of flexion to wrist for 3 weeks. Follow up of the patient was done. Removing the soft drain after 48 h, repeated dressing and cleaning of the wound at intervals till removal of the splint after 21 days. After that they are instructed to have full gentle range of movement of the elbow and the wrist and referred to hand therapist to begin electrical stimulation of intrinsic muscles of hand after.

After 4 weeks beginning of strength training starts and focuses on exercises recruiting the donor nerve, that is, pronation.

Follow up for the patient was done at 3months, 6months & 1 year intervals with clinical examination and EMG of intrinsic muscles.

We used For evaluating the strength of the intrinsic hand muscles, a small modification to the standard Medical Research Council (MRC) grading that has been made so that grade 3 indicates "full active range of motion" as compared to "movement against gravity" in MRC grading [8]:

Grade 5: Full active range of motion and normal muscle resistance.
Grade 4: Full active range of motion and reduced muscle resistance.
Grade 3: Full active range of motion and no muscle resistance.
Grade 2: Reduced active range of motion and no muscle resistance.
Grade 1: No active range of motion and Palpable muscle contraction only.
Grade 0: No active range of motion and no palpable muscle contraction.

As grade 5 considered excellent, grade 4 considered very good result, grade 3 considered as good result and grade 2 or less considered as bad results.

Evaluation of grip strength was done using sphygmomanometer inflated initially to 20 mm Hg and then the patient was asked to squeeze the cuff with both the affected and normal hands on 3 occasions at intervals of 10 s. The maximum height of the mercury column achieved on each occasion was noted and the grip strength taken as the mean of the second and third readings. A reading of the affected hand from 90-100% of the normal hand considered as excellent result, from 70-90% considered as a very good result, from 50-70% considered as fair result and below 50% considered as a poor result [9].

Evaluation of pinch strength was done based on grading of adductor pollicis muscle.

Evaluation of clawing was done based on clinical observation.

STATISTICAL ANALYSIS

Data collected throughout history, basic clinical examination, laboratory investigations and outcome measures coded, entered and analyzed using Microsoft Excel software. Data were then imported into Statistical Package for the Social Sciences (SPSS version 20.0) **(**Statistical Package for the Social Sciences) software for analysis. According to the type of data qualitative represent as number and percentage, quantitative continues group represent by mean ± SD, the following tests were used to test differences for significance; difference and association of qualitative variable by Chi square test (X^2). Differences between quantitative independent groups by t test or Mann Whitney. P value was set at <0.05 for significant results & <0.001 for high significant result. Data were collected and submitted to statistical analysis.

RESULTS

Age distribution among studied group mean was 28.5±6.86 with minimum 18 and maximum 42 years (Table 1). Male were the majority with 75% (9 cases) and female 25% (3 cases). The highest distribution in mode of trauma was road traffic with 41.7%, 58.3% of studied group were affected in their dominant hand and elbow level of injury represent majority with 58.3% (Table 2). The time interval before surgery mean was 4.25±1.48 with minimum 2 months and maximum 6 months (Table 3).

There was significant association between time interval before surgery and motor improvement, the better improvement was significantly associated with shorter Interval before surgery (Table 3). There was significant association compliance to physical therapy and motor improvement (Table 4).

Table 5 showed motor grading of the studied patients 6 months postoperative as majority were grade 3 & 4 motor. All patients as regard to 3rd palmar inter osseous were poor, but all patients as regard Adductor pollicis (fig 1 a&b) were with Very good and good results. As regard to 2nd palmar inter osseous, 1st palmar inter osseous and Dorsal Inter ossii only 16.7% (2 patients) were poor in results (fig 2 a,b,c,d&e)

Table 6 showed improvement distribution from different functional aspects as 75% were very good as regard to **Grip improvement** distribution and 25% with fair results. Regarding **Pinch improvement** 66.7% were very good. Only 33.3% had **Clawing improvement.**

(Video 1) shows the results of a case after one year post-operative.

Table 1: Relation between age and motor improvement of adductor pollicis in the studied patients

	Age
Mean± SD	**28.5±6.86**
Median (Range)	**28.0 (18-42)**

Table 2: Trauma characteristics distribution among studied patients

		N	%
Mode trauma	**Fall from height**	**1**	**8.3**
	Gun shot	**1**	**8.3**
	Machine	**2**	**16.7**
	Road traffic accident	**5**	**41.7**
	Sharp knife	**3**	**25.0**
Affected Dominant hand	**No**	**5**	**41.7**
	Yes	**7**	**58.3**
Level injury	**Arm**	**3**	**25.0**
	Elbow	**7**	**58.3**
	High proximal forearm	**2**	**16.7**
	Total	**12**	**100.0**

Table 3: Relation between time interval before surgery and motor improvement of adductor pollicis in the studied patients

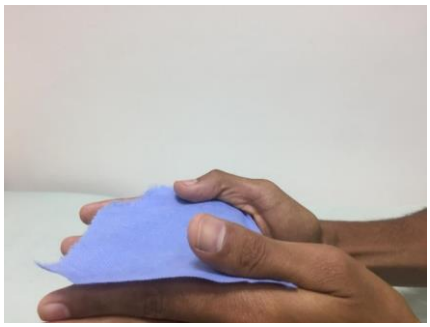
Interval beforev surgery (m)	N of patients	Motor grading		%
0-2 months	**2 16.7%**	**Very good**	**2**	**100**
		Good	**0**	**0.0**
>2-4 months	**5 41.66%**	**Very good**	**4**	**80**
		Good	**1**	**20**
>4-6 months	**5 41.66%**	**Very good**	**2**	**40**
		Good	**3**	**60**
t/ Mann Whitney				**-3.544**
P value				**0.005***

Table 4: Relation between compliance to physical therapy and motor improvement of adductor pollicis in the studied patients

Motor grade	Compliant	Non compliant
Very good	**8 (80%)**	**0 (0%)**
good	**2 (20%)**	**2 (20%)**
Total	**10/12 (83.33%)**	**2/12 (16.67%)**
X^2		**4.8**
P value		**0.028***

Table 5: Motor grading of the studied patients 6 months postoperative

		N	%
3rd palmar inter osseous	Excellent (G5)	0	0.0
	Very good (G4)	0	0.0
	Good (G3)	0	0.0
	Poor (≤G2)	12	100.0
2nd palmar inter osseous	Excellent (G5)	0	0.0
	Very good (G4)	0	0.0
	Good (G3)	10	83.3
	Poor (≤G2)	2	16.7
1st palmar inter osseous	Excellent (G5)	0	0.0
	Very good (G4)	4	33.33
	Good (G3)	6	50
	Poor (≤G2)	2	16.7
Dorsal Inter ossii	Excellent (G5)	0	0.0
	Very good (G4)	5	41.66
	Good (G3)	5	41.66
	Poor (≤G2)	2	16.7
Adductor pollicis	Excellent (G5)	0	0.0
	Very good (G4)	8	66.66
	Good (G3)	4	33.34
	Poor (≤G2)	0	0.0



A

B

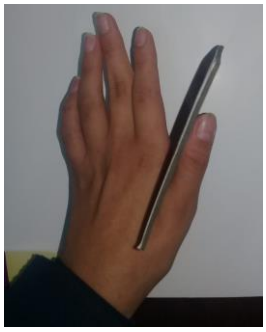
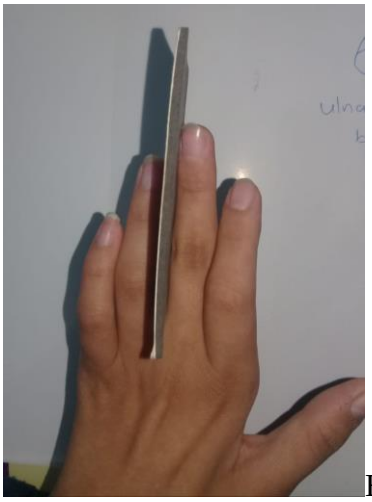
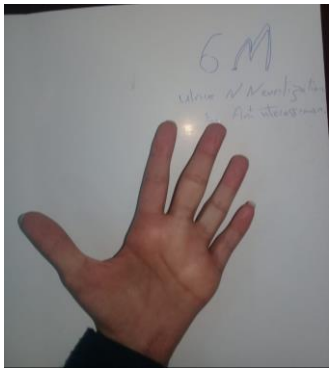


Fig 1: results of adductor pollicics longus muscle a. pre-operative b. after 6 months

A



B



C

D

Fig 2: results of palmar and dorsal inter osseii muscles a. preoperative b&c. 6 months post op d&e. 1 year post op

DISCUSSION

In **1982 Gaul** reported in his study that adults with high ulnar nerve lesions never recovered reasonable function [10]. In ***1993*** **Vastamäki** and his colleagues stated that if the level of injury is more than 60 cm from the tip of the middle finger (i.e. high ulnar nerve lesions) no satisfactory results can be expected [11].

Secer et al., [12] reported the results of repair of ulnar nerve injuries caused by gunshots in 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. In 2007 **Pfaeffle et al.,** [13] noted that all patients with high level ulnar nerve injuries needed tendon transfer surgery because the motor recovery is often weak and clawing usually is not corrected.

In this study the incidence of injury in patients was more in males (9 cases) than females (3 cases). This agree with **Semaya [14], Haase and Chung [15]** and **Flores [16].** The reason of high incidence of injury in males is obvious as their exposure to trauma of different types is higher in most countries.

In this study the mean of age was **28.5±6.86** ranging from **18-42** years old which is comparable with **Semaya [14]** as the mean age of the patients in his study was 24 years (ranging from 17 to 38 years) and **Flores[16]** as the mean of age was 25.2 ranging from 8 to 40 years. While in the study of **Novak and Mackinnon [17]** the mean age was 38 years (ranging from 13 to 71 years) and in the study of **Battiston and Lanzetta [18]** the age of the patients ranged from 11 to 52 years (average, 32 years). This similarity and difference of age groups may be attributed to the different cultural characteristics in different countries.

In our study most of injuries were at level of elbow (7 cases), 3 cases at arm and 2 cases at proximal level of forearm. In 1999 **Battiston and Lanzetta [18]** treated 6 casaes at the level of elbow and 1 above elbow at mid-arm**, Flores, 2011 [16]** reported 2 cases at the level of arm, 1 at elbow level, 1 at axilla level and 1 at the Infra-clavicular level**. Semaya[14]** managed 2 cases at mid-arm 1 at elbow, and 1 at axilla while **Haase and Chung [15]** managed 2 cases at mid-arm level. This shows that majority of injuries are at the level of elbow and arm. These sites are the most prone sites to injury from anatomical point of view during daily activity.

In our study the mean interval from injury to surgery was **4.25±1.48** ranging from 2 to 6 months. **Semaya [14]** in their study the mean was 3.25 ranging from 2.5 to 5 months. In the study of **Flores[16]** the mean time interval from injury to surgery was 7.4 months (range 4 to 10 months)**. Battiston and Lanzetta [18]** in their study the mean interval was 4 ranging from 1 to 6 months. In the study of **Novak and Mackinnon [17]** the mean time from injury to surgery was 3 months (ranging from 0 to 10 months).

In our study follow up to patients ranged from 6 to 12 months postoperative.

Novak and Mackinnon [17] mean follow up to their patients postoperative was 18 months. In the study of **Battiston and Lanzetta** [18] the length of the follow-up period was between 1 and 3.5 years (average, 2.5 years)**.** **Flores** [16] postoperative follow-up time mean was 20 months (ranging from 15 to 30 months)**.** In the study of **Semaya** [14 the mean postoperative follow-up period was 22 months (ranging from 12 to 38 months).

The short follow up in our study is a drawback. However, we will follow our patients in the future for longer period to see the long term results. However, the results after 6 months of follow up are encouraging. Also this may refer to presence of excellent results at other studies due to long postoperative time of follow up for years**.**

In this study, good motor recovery (G3 or G4) was observed in patients. The Adductor pollicis longus muscle recovered (G3) in four patients and (G4) in the other eight patients. This resulted in good postoperative lateral pinch and grip strength.

In this study, good motor recovery was observed in dorsal inter-ossei muscles in 10 patients to (5 patients had G4 & 5 patients had G3 and 2 patients was of poor results (G2).

As regard to abductor of fingers improvent was observed in 1st and 2nd palmar inter-ossei (G3) in 10 patients and 2 patients had poor outcome (G2).

The abductor of little finger was observed poor in all patients (G1&G2) with persistence of Wartenburg sign in all 12 patients.

In 2002 **Novak and Mackinnon,** [17] reported eight patients with high ulnar nerve injuries 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 good recovery of the ulnar nerve intrinsic hand muscles, with improved postoperative lateral pinch and grip strength.

In 2002 **Haase and Chung** [15] 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 recovery of function to the ulnar-innervated small muscles of the hand in these two cases.

Wang and Zhu [19] 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 done 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.

In 1999 **Battiston and Lanzetta,** [18] treated seven patients with high ulnar nerve injuries 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 respectively at the wrist. They reported good motor recovery (M3 or M4) in six out of seven cases and all of them achieved S3+.

In 2011 **Flores,** [16] treated 5 patients with high ulnar nerve injury by double distal neurotization of the AIN to deep motor branch of ulnar nerve and end to side suture of the superficial ulnar nerve to the third common palmar digital nerve with good results (M4&3) to all five patients.

In 2015 **Semaya** [14] managed 4 cases of high ulnar nerve injury using distal double nerve transfer using motor and sensory branches from the median nerve and reported 3 cases with (M4&3) with 1 case graded M1.

Our results following AIN to deep motor branch of ulnar nerve are close to the previous studies.

Our findings imply that better outcomes are significantly associated with shorter Interval before surgery and postoperative compliance to hand therapy agreeing with **Secer et al., 2007** [10]**.**

In our results we found most of cases had no improvement in clawing so we suggest doing tendon transfer as a secondary operation to improve clawing.

This study has some limitations. The 8 months follow-up might not be sufficient to evaluate long-term recovery.

CONCLUSION

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

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Funding information

Non declared

REFERENCES

1. **Woo A, Bakri K, Moran SL.** Management of ulnar nerve injuries. The Journal of hand surgery (2015); 40(1): 173-181.
2. **Jones NF & Machado GR.** Tendon transfers for radial, median, and ulnar nerve injuries: current surgical techniques. Clinics in plastic surgery (2011); 38(4): 621-642.
3. **Davis TRC.** Median and ulnar nerve palsy. In: Wolfe SW, Hotchkiss RN, Pederson WC, Kozin SH, eds. Green's Operative Hand Surgery. New York: Churchill Livingstone (2011): 1115-1135.
4. **Menorca RM, Fussell TS, Elfar JC.** Peripheral nerve trauma: mechanisms of injury and recovery. Hand clinics (2013); 29(3): 317–330.
5. **Sassu P, Libberecht K, Nilsson A**. Nerve transfers of the forearm and hand: a review of current indications. Plastic and Aesthetic Research (2015); 2(4): 195-195.
6. **Brown JM, Yee A, Mackinnon SE.** Distal median to ulnar nerve transfers to restore ulnar motor and sensory function within the hand: technical nuances. Neurosurgery (2009); 65(5): 966-978.
7. **Sharma M. S, Bishop AT, Shin AYS, Spinner RJ.** Nerve Transfers: Indications and Techniques. In: Schmidek and Sweet's Operative Neurosurgical Techniques (2012): 2261-2271.
8. **Schreuders TA, Selles RW, Roebroeck ME, Stam HJ.** Strength measurements of the intrinsic hand muscles a review of the development and evaluation of the Rotterdam intrinsic hand myometer. Journal of Hand Therapy (2006); 19(4): 393-402.
9. **Yahin A, Moeliono MA, & Prananta MS.** Handgrip strength prediction formula using aneroid sphygmomanometer in elderly. *International Journal of Integrated Health Sciences* (2016); *4*(2): 47-55.
10. **Gaul Jr JS.** Intrinsic motor recovery—a long-term study of ulnar nerve repair. The Journal of hand surgery (1982); 7(5): 502-508.
11. **Vastamäki M, Kallio PK, Solonen KA.** The results of secondary microsurgical repair of ulnar nerve injury. Journal of Hand Surgery (1993); 18(3): 323-326.
12. **Secer HI, Daneyemez M, Gonul E, Izci Y.** Surgical repair of ulnar nerve lesions caused by gunshot and shrapnel: results in 407 lesions. Journal of neurosurgery (2007); 107(4): 776-783.
13. **Pfaeffle HJ, Waitayawinyu T, Trumble TE.** Ulnar nerve laceration and repair. Hand clinics (2007); 23(3): 291-299.
14. **Semaya A.** Reconstruction of high ulnar nerve lesions by distal double neurotization using motor and sensory branches from the median nerve. The Egyptian Orthopaedic Journal (2015); 50(2): 122-126.
15. **Haase SC & Chung KC.** Anterior interosseous nerve transfer to the motor branch of the ulnar nerve for high ulnar nerve injuries. Annals of plastic surgery (2002); 49(3): 285-290.
16. **Flores LP.** Distal anterior interosseous nerve transfer to the deep ulnar nerve and end-to-side suture of the superficial ulnar nerve to the third common palmar digital nerve for treatment of high ulnar nerve injuries: experience in five cases. Arquivos neuro-psiquiatria (2011); 69(3): 519-524.
17. **Novak CB & Mackinnon SE.** Distal anterior interosseous nerve transfer to the deep motor branch of the ulnar nerve for reconstruction of high ulnar nerve injuries. Journal of reconstructive microsurgery (2002); 18(06): 459-464.
18. **Battiston B & Lanzetta M.** Reconstruction of high ulnar nerve lesions by distal double median to ulnar nerve transfer. The Journal of hand surgery (1999); 24(6): 1185-1191.
19. **Wang Y & Zhu S.** Transfer of a branch of the anterior interosseus nerve to the motor branch of the median nerve and ulnar nerve. Chinese medical journal (1997); 110(3): 216-219.

How to Cite

maohammed, S., anani, R., wahsh, M., mehanna, A. early neurotization of high ulnar nerve injury using anterior interosseous nerve for restoration of intrinsic muscles function. *Zagazig University Medical Journal*, 2021; (735-744): -. doi: 10.21608/zumj.2019.15527.1385