THE USE OF TENDON TRANSFER IN THE MANAGEMENT OF PERIPHERAL NERVE INJURIES OF THE UPPER LIMB

Protocol of Thesis

Submitted for fulfillment of the requirement for the Masters Degree in Surgery

By

Guirgis Arsanios Awad Shehata
(M.B.B.Ch) _ Cairo University

Supervised by

Prof. Dr. Maamoun Ismail Maamoun

Professor of General and Plastic Surgery
Faculty of Medicine
Cairo University

Prof. Dr. Adel M. Wilson

Professor of General and Plastic Surgery
Faculty of Medicine
Cairo University

Ass .Prof. Dr. Tarek A. Amer

Assistant Professor of General and Plastic Surgery
Faculty of Medicine
Cairo University

Faculty of Medicine
Cairo University – 2010

ACKNOWLEDGEMENT

I shall never forget to remember The One without whose grace and support I wouldn't have been or survived. All thanks and praises are due to our ***Loving God***.

I am really so grateful to my very respectful and honestly loveable supervisors. I was very lucky to get in direct contact with these great persons;

Prof.Dr.Maamoun Ismail Maamoun, a very modest person and a true human being, before being scientifically, clinically and socially a great and an eminent professor.

Also ***Prof.Dr.Adel M. Wilson***, an intelligent and talented professor, yet a very friendly and supportive person.

At last and not least, ***Ass.Prof.Dr.Tarek A.Amer***, a skillful and enthusiastic plastic& reconstructive surgeon, yet a committed, modest and very helpful person.
I am so grateful to them for their sincere efforts, time and convenient directions. May God bless all of them and grant them peace and ongoing success in all aspects of their life.

I am also grateful to **Dr. Mahmoud Abdel Rahman**, (Head of plastic surgery department_ El Sahel teaching hospital) and **Dr. Hossam Eldin Mohamed**, (Consultant plastic surgery _El Sahel Teaching hospital), for their ultimate help and support. Despite of finishing my residency at their hospital, they never stopped helping me and showing much concern.

For my whole life I will be so grateful to my loving, self sacrificing and very supporting parents;
F.Arsanios Awad *and* ***Mrs Aida Youssef****. May God bless their whole life and grant them good health and everlasting peace.*

ABSTRACT

Nerve impairment in the hand probably constitutes its major disability. The functional outcome after nerve repair is determined by numerous factors. As rule in all cases of never injury, the nerve must be repaired as soon as it is diagnosed and should not be unduly delayed, but done alone may result in frustrating outcome.

Tendon transfers follow a basic concept that nothing new is created but functional parts are rearranged into the best possible working combination i.e. involve redistribution, not creation, of new power units. These involve detachment of the tendon distally, careful mobilization and rerouting it to a new distal attachment.

The aim of this thesis is to give a general idea about the most common methods for tendon transfers done for the various peripheral nerve injuries of the upper limb and its effect on the patient.

This study included **10 patients** with different nerve injuries of the upper limb. The ***median nerve*** was injured in **2** patients, the ***ulnar nerve*** in **3** patients, and the ***radial nerve*** in **4** patients. **One** patient had a ***combined low median and ulnar nerve injury***. Tendon transfer was done, after more than six months of the nerve injury and epineural repair in 8 patients. In the two remaining patients, who had posterior interosseous nerve injury in the proximal third of the dorsum of the forearm, tendon transfer was done after 4 months of the injury.

In general, early tendon transfer acts as a temporary substitute for the paralyzed muscle until reinnervation occurs; so it acts as an internal splint. If reinnervation is suboptimal, early tendon transfer acts as a helper to augment the power of the muscle. If reinnervation fails to occur, the tendon transfer acts then as a permanent substitute.

Key words; median nerve injury, ulnar nerve injury, radial nerve injury, combined nerve injury, tendon transfer.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Ab,P.B : Abductor pollicis brevis
Ab.P.L : Abductor pollicis longus
Ab.D.M : Abductor digiti minimi
Ad.P : Adductor pollicis
Br.Rad. : Brachio radialis
CMAP : Compound muscle action potential
ECRB : Extensor carpi radialis brevis
ECRL : Extensor carpi radialis longus
EDC : Extensor digitorum Communis
EPB : Extensor pollicis brevis
EPL : Extensor pollicis longus
EDM : Extensor digiti minimi
EIP : Extensor indicis proprius
FCR : Flexor carpi radialis
FCU : Flexor carpi ulnaris
FDS : Flexor digitorum superficialis
FDP : Flexor digitorum profundus
FPL : Flexor pollicis longus
FPB : Flexor pollicis brevis
PL : Palmaris longus
PT : Pronator teres
Op.P : Oppenens pollicis
Op.D.M : Opponens digiti minimi

INTRODUCTION

The hand is a complex machine. It is an organ of grasp of fine movement and is also an organ of sensation and fine discrimination. The large portion of the brain that represents and controls the hand is an evidence of its ultimate importance.

Nerve impairment in the hand probably constitutes its major disability. The functional outcome after nerve repair is determined by numerous factors such as the level of injury, the age of the patient, delay in the repair and the skill of the surgeons. As rule in all cases of never injury the nerve must be repaired as soon as it is diagnosed and should not be unduly delayed ***(Watchmeker, and Mackinnon, 1997).***

Tendon transfers follow a basic concept of reconstructive surgery: Nothing new is created but functional parts are rearranged into the best possible working combination i.e. involve redistribution, not creation, of new power units. These involve detachment of the tendon distally, careful mobilization and rerouting it to a new distal attachment. These procedures are among the most interesting and rewarding of upper limb surgery ***(Beasley, 2007).***

Immediate tendon transfer is only done if there is no chance of neurologic recovery (i.e. destroyed muscle or large segment of the nerve is missing and repair / regrowth is not feasible). Delayed tendon transfer is usually performed 9 to 12 months following nerve injury to allow for potential regrowth of the nerve. The higher the nerve injury, the longer regrowth will take ***(Walter, 2004).***

AIM OF WORK

The aim of this study is to assess the efficacy of the variable methods of tendon transfers in upper limb and its role in restoration of the best possible motor function following peripheral nerve injuries in the upper limb.

PATIENTS AND METHODS

Tendon transfer will be done for ten (10) patients with motor defects following different peripheral nerve injuries of the upper limb. Pre and post operative evaluation will be done via: Clinical examination of motor power and function, nerve conduction and EMG and X- Ray imaging and Photography.

ANATOMY OF THE HAND

The hand is a complex machine; so intricate in its construction and function, that great detail must be given to the discussion of its anatomy. The hand is an organ of grasp as well as of fine movements. It is an organ of sensation and fine discrimination. The large portion of the brain that controls the hand is an evidence of the complexity of this organ **(Sinnatamby, 1999)**.

I-Fascia of the hand

Deep connective tissue of the hand plays an important role in retention and gliding of the tendons. It is organized in a specific manner to prevent bowstringing of tendons.

I)Dorsal aspect

The deep fascia on the dorsum of the hand is arranged in two layers, a *superficial layer*, which covers the extensor tendons and is continuous with the extensor retinaculum and a *deep layer*, which cover the interossei. Usually the deep fascia becomes very thin distally and blends with dorsal superficial fascia, ***(Lamb and Kuczynski, 1989).***

The extensor retinaculum is a thickening of deep fascia that stretches across the back of the wrist and holds the long extensor tendons in position. It converts the grooves on the posterior surface of the distal ends of the radius and ulna into six separate tunnels for the passage of the long extensor tendons. Each tunnel is lined with a synovial sheath, which extends above and below the retinaculum on the tendons. The tunnels are separated from one another by fibrous septa that pass from the deep surface of the retinaculum to the bones.

The retinaculum is attached medially to the pisiform bone and the hook of the hamate and laterally to the distal end of the radius. The upper and lower borders of the retinaculum are continuous with the deep fascia of the forearm and hand, respectively ***(Snell, 2008).***

ii) Palmar aspect

The deep fascia on the palmar aspect of the hand prevents bowstringing of the tendons in several ways:

- ***The flexor retinaculum:*** (transverse carpal ligament) It is a tough, unyielding band serves to contain the tendons of flexor pollicis longus, flexor digitorum superficialis

and flexor digitorum profundus, as well as, the median nerve. Its bony attachments are the tubercle of scaphoid and ridge of the trapezium laterally and the hook of hamate and pisiform medially ***(Kulick, 1996)***.

- ***Palmar aponeurosis:*** It is a strong unyielding ligament extends, in continuity with the tendon of palmaris longus, from the distal border of the flexor retinaculum, it fans out in a thick sheet towards the bases of the fingers. It divides into four slips one for each finger. Each slip gives off superficial fibers that insert into the skin in the region of the creases at the base of the finger, while the main part divides into two bands over the proximal end of the fibrous flexor sheath, they are inserted into the deep transverse ligament of the palm, into the bases of the proximal phalanges and into the fibrous flexor sheath. Over the hypothenar muscles the deep fascia is much thinner than the palmar aponeurosis and is the thinnest of all over the thenar muscles ***(Sinnatamby, 1999)***.
- ***Transverse ligaments of the palm:*** The superficial transverse ligament of the palm lies beneath the palmar skin across the free margin of the webs. The deep transverse ligament of the palm joins the palmar ligaments and the metacarpophalangeal joints. It lies one inch proximal to the superficial transverse ligament. The interosseous tendons lie on the dorsal side of the deep transverse ligament, while the lumbrical tendons are on its palmar side ***(Sinnatamby, 1999)***.
- **Digital fibro-osseeous sheath:** The fibro-osseous sheath is a synovial-lined canal that originates from the periosteum and encloses the flexor tendons in the digits.The sheath is a multilayered double walled covering.The synovial lubricating fluid is rich in hyaluronate and protein,which contributes to the nutrition of the tendon through imbibition as well as providing lubrication for gliding.It extends from the distal palmer crease to just beyond the (DIP) joint.

  The pulley system is formed of thickenings of the sheath that keep the tendons tight to the bones regardless of the position of the fingers or the wrist.It maintains a constant moment arm of force and prevents bowstringing. There are five annular (A) pulleys and three thinner, collapsible crisscross cruciate (C) pulleys for each of the medial four fingers. The thumb has two annular pulleys (at proximal and distal phalynx) and an oblique pulley between them. The A-2 pulley (found at the proximal portion of the proximal phalynx) and A-4 pulley (found at the middle portion of the middle phalynx), are two pulleys that should be preserved to prevent flexor tndon bowstringing in the medial four fingers. The oblique pulley in the thumb is the most important one that needs to be preserved ***(Zidel, 2007)***.

- **The Guyon tunnel:** It is bounded dorsally by the flexor retinaculum, medially by the pisiform bone and the distal part of the tendon of flexor carpi ulnaris, anteriorly it is roofed by the superficial fibers of the deep fascia extending from the flexor retinaculum to the pisiform bone. It is a narrow triangular space through which the ulnar nerve and artery pass to the palm ***(Khoo et al., 1996)***.

II-Muscles concerned with movement of the hand:

i)Muscles acting on the wrist & forearm (flexors and extensors)

ii)Muscles acting on the digits and thumb(extrinsic and intrinsic)

i)Muscles acting on the wrist& forearm: *(Flexor group & Extensor group)*

- ***Flexor group****(FCR-PL-FCU-PT)*

1) Flexor carpi radialis

It arises from the medial epicondyle via the common flexor tendon, from the antebrachial fascia and from the adjacent intermuscular septa. It a long tendon which passes through a lateral canal formed by the flexor retinaculum. The tendon is inserted at three locations. A small slip is connected to the trapezial crest; the major part of the tendon is inserted on the base of the second metacarpal and very small part is inserted on the base of the third metacarpal **(*Bishop et al., 1994).***

***Nerve supply*:** The median nerve, C6 and C7.

Actions: Acting with flexor carpi ulnaris to flex the wrist and acting with radial extensors of the wrist to radial deviate the hand. It can be used to restore extension of the wrist and fingers in radial nerve palsy or thumb opposition in low median nerve palsy. In both cases it is not the best transfer, although it gives power, but shorter range of motion, influenced by wrist movement ***(Warren, 1999)***.

2) Palmaris longus

It arises from the medial epicondyle of humerus by the common flexor tendon, from adjacent intermuscular septa and deep fascia. The muscle converges on a long tendon, which passes superficial to the flexor retinaculum to be inserted into the palmar aponeurosis. Sometimes it may be absent ***(Depuydt et al., 1998).***

Nerve supply: The median nerve C7 and C8

Actions: The muscle is functionally negligible, but it has the advantages of easy access, appropriate length and it is ideal for free tendon graft ***(Koo and Roberts, 1997)***. Also it is used as a tendon for transfer to the thumb to achieve opposition and abduction ***(Saeed and Kay, 1993)***. The tendon could be elongated if needed, by an extension of approximately 5 cm in length and 1 cm width from the longitudinal fibers of palmar aponeurosis, which can be dissected in continuity with the tendon **(*Tolat and Stanley, 1993)***.

3) **Flexor carpi ulnaris**

It arises by two heads, humeral and ulnar, connected by a tendinous arch, under which the ulnar nerve and the posterior ulnar recurrent artery pass. The small humeral head arises from the medial epicondyle via the common flexor tendon, the ulnar head has an extensive origin from the medial margin of the olecranon and the proximal two thirds of the posterior border of the ulna by an aponeurosis shared with extensor carpi ulnaris and flexor digitorum profundus and from the intermuscular septum between it and flexor digitorum superficialis. A thick tendon forms along the anterolateral border of the muscle in its distal half and it is attached to the pisiform bone, a sesamoid, thence prolonged to the hamate and fifth metacarpal bone by the so called pisohamate and pisometacarpal ligaments, a few fibers blend with the flexor retinaculum. Ulnar nerve and artery lie lateral to the tendon.

Nerve supply: The ulnar nerve C7 **-** 8 and T1.

Actions: With the flexor carpi radialis it flexes the wrist, while with extensor carpi ulnaris it ulnar deviates the hand **(*Salmons, 1995)***.

The flexor carpi ulnaris is an expandable muscle, so it can be used for restoring fingers and thumb extension in radial nerve palsy or thumb opposition in low median nerve palsy. There are two problems that together make it reluctant to use these transfers today. The first is that, its muscle fibers are not long enough to allow a full range of finger extension. The second problem is that, the flexor carpi ulnaris is important in its own position as an ulnar deviator. A large number of common actions like hammering and chopping need ulnar stabilization or ulnar deviation of the wrist ***(Brand, 1990)***.

4) **Pronator teres**

It has humeral and ulnar attachment. The humeral head arises just proximal to the medial epicondyle, from the common flexor tendon, from the intermuscular septum between it and the flexor carpi radialis and from antebrachial fascia. The smaller ulnar

head arises from the medial side of the coronoid process of the ulna and join the humeral head at an acute angle. In 83% of cases the median nerve enters the forearm between the two heads and is separated from the ulnar artery by the ulnar head. The muscle passes obliquely across the forearm to end in a flat tendon that is attached to a rough area midway along the lateral surface of radial shaft.

***Nerve supply*:** The median nerve C6 and C7.

***Actions*:** Pronation of the forearm and weak flexion of the elbow ***(Salmons, 1995)*.**

Transfer of pronator teres into the extensor carpi radialis brevis to restore active wrist extension is the classic procedure in radial nerve injuries. The pronator teres is, well situated anatomically, has adequate power and excursion and is easily re-educated. With its new insertion into the extensor carpi radialis brevis over the radius, it continues to function well as a forearm pronator ***(Dunnet et al., 1995)*.**

- **Extensor group** *(ECRL-ECRB-ECU)*

1) Extensor carpi radialis longus

It arises mainly from the distal third of lateral supracondylar ridge of the humerus and from the front of the lateral intermuscular septum; some fibers come from the common extensor tendon. Its flat tendon passes under the extensor retinaculum to be inserted on the radial side of dorsal surface of the base of the second metacarpal. It may send slips to the first or third metacarpal.

Nerve supply: The radial nerve C6 and C7.

***Actions*:** Acting with the extensor carpi ulnaris the two radial extensors extend the wrist and with the flexor carpi radialis the two muscles abduct the hand **(*Salmons, 1995)*.** The extensor carpi radialis longus can be used for correction of claw hand deformity in ulnar nerve injuries. It is a good transfer and is easy to re-educate. It provides adequate but not strong power. It can also used to restore strong opposition of the thumb **(*Warren, 1999)*.**

2) Extensor carpi radialis brevis

It arises from the lateral epicondyle of humerus from the common extensor tendon, from the radial collateral ligament of the elbow joint, from strong aponeurosis, which covers its surface and from adjacent intermuscular septum. Its belly ends at about midforearm in a flat tendon, which passes under extensor retinaculum to be inserted

on the dorsal surface of the base of the third metacarpal on its radial side and adjoining part of the second metacarpal base.

***Nerve supply*:** The posterior interosseous nerve C7 and C8.

Actions: It extends the wrist with other extensors and with the extensor carpi radialis longus and flexor carpi radialis it abducts the hand **(*Salmons, 1995)*.** The extensor carpi radialis brevis may be used as a transfer for correction of claw hand deformity **(*Brand, 1990)***.

3) Extensor carpi ulnaris

It arises from the lateral epicondyle via the common extensor tendon, from the posterior border of the ulna by an aponeurosis shared with flexor carpi ulnaris and flexor digitorum profundus and from overlying fascia. It ends in a tendon, which passes in a separate compartment of the extensor retinaculum. It is attached to a tubercle on the medial side of the fifth metacarpal base

***Nerve supply*:** The posterior interosseous nerve C7 and C8.

***Actions*:** Together with the radial extensors, it acts synergistically with the digital flexors to extend and to fix the wrist when objects are being gripped or when the fist is clenched. Acting with flexor carpi ulnaris, it deviates the hand ulnary. The muscle has an important role in maintaining wrist stability **(*Salmons, 1995)*.**

ii)Muscles acting on the digits and thumb

A)Extrinsic muscles acting on the digits: (Flexor group & Extensor group)

(I)Flexor group (FDS-FDP)

1. Flexor digitorum superficialis

Arises by two heads, *the humero-ulnar head* arises from the medial epicondyle of humerus via the common flexor tendon, from the anterior band of the ulnar collateral ligament, from adjacent intermuscular septa and from the medial side of the coronoid process proximal to the ulnar origin of the pronator teres. *The radial head* arises from the anterior radial border extending from the radial tuberosity to the insertion of pronator teres. The median nerve and ulnar artery descend between the two heads.

As the tendons pass beneath the flexor retinaculum, the middle and ring finger tendons lie superficial to those to the index and little fingers. At the proximal third of the

proximal phalanx, the superficialis tendon splits to pass around the flexor digitorum profundus tendon. These two slips then reunite deep to the profundus tendon with decussation of some of their fibers, to from *the Camper's chiasm.* Beyond this chiasm, the superficialis tendon divides into radial and ulnar slips which insert into the proximal third of the middle phalanx **(*Steinberg, 1992)*.**

***Nerve supply*:** The median nerve in the forearm C7**-** 8 and T1.

***Actions*:** It is a flexor of the proximal interphalangeal joints and secondarily of the metacarpophalangeal and wrist joints **(*Sinnatamby, 1999)*.**

The flexor digitorum superficialis is *responsible for the power of the grip,* while the profundus has more range of motion. The index and little fingers are used to hold firmly on objects, while the ring and middle fingers are only supportive so flexor digitorum superficialis of the latter two fingers is expandable and can be transferred without much loss of movement. The use of flexor digitorum superficialis of the ring finger to correct claw hand and that of the middle finger to restore thumb adduction is the transfer of choice in ulnar nerve palsy. Care should be taken, as excessive tension tends to produce an intrinsic plus deformity. It can also be used to restore wrist and fingers extension, the transfer is strong, easily re-educated and provides a good range of movement, but transfer of the two flexor tendons to the extensor side may weaken the grip **(*Warren, 1999)*.**

2. Flexor digitorum profundus

It arises deep to the superficial flexors from about the upper three quarters of the anterior and medial surfaces of the ulna and extending distally almost to pronator quadratus. It also arises from a depression on the medial side of the coronoid process, from the upper three quarters of the posterior ulnar border by an aponeurosis shared with flexor and extensor carpi ulnaris and from the anterior surface of the ulnar half of the interosseous membrane.

In the midforearm, the muscle divides into two bellies. The radial one gives rise to the profundus tendon to the index finger. The ulnar belly forms the tendons to the rest of the fingers near the flexor retinaculum. Just distal to the carpal tunnel, the lumbrical muscles originate from the profundus tendons. At the mid proximal phalanx, the profundus tendon passes through the split in the superficialis tendon and lies in a more palmar position. It continues distally to its broad insertion into the base and the proximal third of the distal phalanges ***(Steinberg, 1992).***

Nerve supply*:** The ulnar half of the muscle (to the ring and little fingers) is supplied by branches of the ulnar nerve (C8 and T1). The radial half is supplied by branches of the anterior interosseous nerve (C7**-** 8 and T1). Occasionally either of the above nerves may supply the whole muscle ***(Lamb and Kuczynski, 1989).

Actions*:** It helps to flex all the joints it crosses but its primary action is to flex the distal interphalangeal joints ***(Sinnatamby, 1999).

(II)Extensor group (EDC-EI-EDM)

1. Extensor digitorum(communis) :

It arises from the lateral epicondyle of humerus via the common extensor tendon, from the adjacent intermuscular septa and from the antebrachial fascia. It ends into four tendons proximal to the wrist and pass deep to the extensor retinaculum ***(Blair et al, 1992)***.

The long extensor tendon at the level of MCP joints divides into three bands. Its direct continuation proceeds along the dorsum of the proximal phalanx, while the transverse fibers embedded in the proximal edge of the extensor expansion encircle the metacarpal head to fuse with the deep transverse ligament of the palm; this attachment of the muscle limits its proximal retraction. The main portion of the tendon before reaching the proximal interphalangeal joint divides into three terminal bands. A central one is attached to the middle phalanx. Two lateral bands, which at first lie in the groove over the lateral part of the dorsum of the proximal interphalangeal joint, converge to be attached to the base of the distal phalanx. All these elements of the extrinsic tendinous component are bounded together by oblique and transverse fibers embedded in the flat triangular extensor expansion ***(Rayan et al., 1997)*.**

***Nerve supply*:** Posterior interosseous nerve (C7 and C8).

Actions: The muscle primarily extends the metacapophalangeal joints. It assists also in extension of the interphalangeal and wrist joints **(*Blair et al, 1992)***

2. **Extensor indicis**(proprius)

It arises deep in the forearm from the lower part of the ulna and adjoining interosseous membrane. Its tendon passes through the extensor retinaculum in accompany with extensor digitorum. In the dorsum of the hand the tendon *lies on the ulnar side of the index tendon of the extensor digitorum*. At the metacarpophalangeal joint level, the