The Split Flexor Carpi Radialis Transfer in Radial Nerve Paralysis

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ABSTRACT

Background *In the modified Tsuge tendon transfer for radial nerve palsy, tendon bowstringing occurs after transferring the palmaris longus to the rerouted extensor pollicis longus leading to loss of thumb extension. Therefore, the effect of a split flexor carpi radialis transfer to restore extensor pollicis longus and extensor digitorum functions separately was investigated.* ***Materials and Methods:*** *7 male patients suffering from late high radial nerve palsy were treated with the split flexor carpi radialis technique and followed up for 2 years. To achieve wrist extension, the tendon of pronator teres (PT) was transferred to the extensor carpi radialis brevis (ECRB) distally. Extension of the fingers and of the thumb were restored with a split flexor carpi radialis (FCR)* ***Results:*** *Improvements were recorded in wrist extension (range: 50°) and flexion (range: 40°), finger extension (range: 30°), thumb extension (range: 65°), radial abduction (range: 36°), thumb abduction (range: 40°) A palmaris longus to abductor pollicis transfer was carried out in 2 patients, however. Grip strength improved to 63% of that of the contralateral hand.* ***Conclusions:*** *Pronator teres transfer to extensor carpi radialis brevis restores wrist extension efficiently; the split flexor carpi radialis transfer to extensor pollicis longus and extensor digitorum restores function separately to each muscle. No tendon bowstringing occurs. To enhance thumb abduction, the transfer may be augmented in certain cases with Palmaris longus to abductor pollicis longus transfer.*

INTRODUCTION

In patients suffering from radial nerve paralysis wrist extension, finger extension, thumb extension and thumb abduction should be restored. Riordan's procedure [1, 2] includes the transfer of the pronator teres to the extensor carpi radialis brevis (ECRB), the flexor carpi ulnaris (FCU) to the extensor digitorum communis (EDC), and the palmaris longus (PL) to the extensor pollicis longus (EPL). This was modified by Tsuge[3,4]. Tsuge aims at preserving the flexor carpi ulnaris muscle, as it is the most important muscle involved in hand grip. In his procedure, the pronator teres (PT) is transferred to the ECRB, the flexor carpi radialis (FCR) is transferred to the EDC through a window made in the interosseous membrane of the forearm. The palmaris longus (PL) is then transferred to the volarly rerouted extensor pollicis longus (EPL). The latter transfer might, however, lead to bowstringing of the transferred tendon[5], so that it loses its extensor function and is converted to a wrist abductor. The aim of this study is to evaluate the following: the effect of a split flexor carpi radialis transfer to restore extensor pollicis longus and extensor digitorum functions separately; the effect of pronator teres to extensor carpi radialis transfer on restoring wrist function.

MATERIALS & METHOD

Patients

Seven male patients were treated with the split flexor carpi radialis technique and followed up for 2 years. The right hand was affected in 5 patients and the left hand in 2. The dominant hand was affected in 6 patients. Age at operation ranged from 20 to 40 years with a mean of 30 years.

Causes of radial nerve palsy

Causes of radial nerve palsy included: fracture of the humerus in 6 patients, intraoperative disruption of the radial nerve in 1. High radial nerve paralysis was observed in all 7 patients.

Timing

Average period between onset and operation was 17months

Preoperative electromyography

Preoperative electromyography was performed in all of them. Surgery was undertaken, if there was no evidence of summation potentials on voluntary contraction.

Operative Procedures (Figs 1a-d and 2 a-d)

To achieve wrist extension, the tendon of pronator teres (PT) was transferred to the extensor carpi radialis brevis (ECRB) distally. In two patients, the tendon of PT was attached to both the ECRB and the ECRL. In these two cases, a ‘‘medialisation’’ of the ECRL was also carried out; the distal insertion of the ECRL was detached and attached to the ulnar aspect of the third metacarpal, as described by Tubiana[6].

Extension of the fingers and of the thumb were restored with a split flexor carpi radialis (FCR)[7]. The insertion of the FCR tendon was divided and by applying tension to the cut end, the muscle was split into 2 compartments along the tendon and the aponeurosis all the way to its proximal fifth[8]. Care was taken not to divide the separate vascular and nerve pedicles entering each compartment. The smaller ulnar-sided tendon was passed radially and subcutaneously and woven into the extensor pollicis longus tendon while the radial tendon was passed dorsally and woven into the tendons of the extensor digitorum communis.

Following other authors[7], tensioning of the transfers was performed with the wrist and metacarpophalangeal joints in neutral and both heads of the FCR stretched. A splint was applied to hold the wrist extended 45° distally to the maximum length, the metacarpophalangeal joints at 10° of flexion, and the interphalangeal joints extended. Active movements were started 3 weeks after surgery. A rehabilitation program with emphasis on separating extensor pollicis longus and extensor digitorum communis function was instituted at the end of the 3-week period. At 6 months after surgery the patient was able to flex his thumb while extending his fingers and conversely extend his thumb while flexing his fingers

In order to restore thumb abduction, the palmaris longus (PL) was sutured to the abductor pollicis longus (APL) in three patients at a second stage.

RESULTS

Wrist extension and flexion

Postoperatively, average wrist extension was 50° (20°–70°) and wrist flexion was 40° (20°–60°).

Finger extension

Active extension of the metacarpophalangeal (MCP) joint of the middle finger was 30° measured with the wrist in neutral extension. Average finger extension was 30°. Both active extension of the fingers with the wrist in the extended position and active flexion of the wrist with the fingers in the flexed position were limited.

Thumb extension

Average hyperextension of the interphalangeal (IP) joint of the thumb was 5° while the average range of motion of the interphalangeal joint was 65°.

Thumb abduction

Thumb abduction ranged from 20 - 60 degrees, with an average of 40 degrees. In 2 patients, thumb abduction was limited to 20 degrees. A palmaris longus to abductor pollicis transfer was

carried out in both of them. This procedure restored thumb abduction range to 40 degrees.

Radial abduction

Average radial abduction of the thumb was 36°.

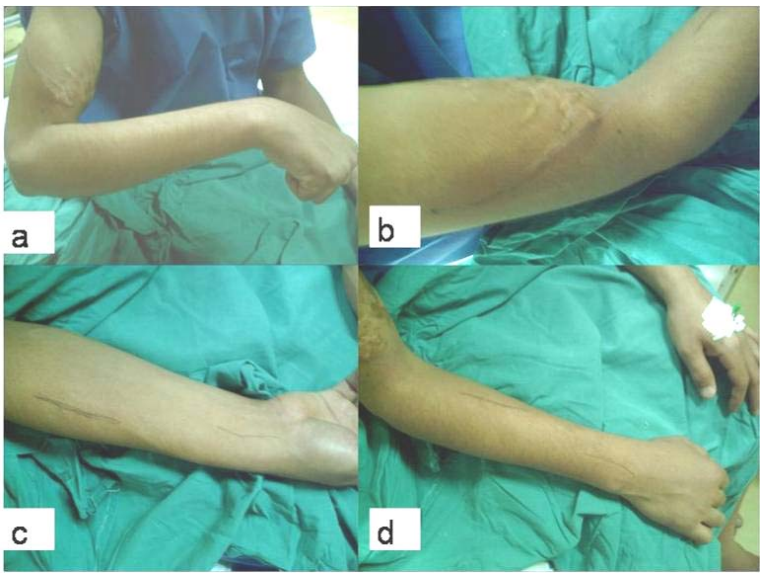
Radial deviation of the wrist was observed in three patients.

Tendon bowstringing

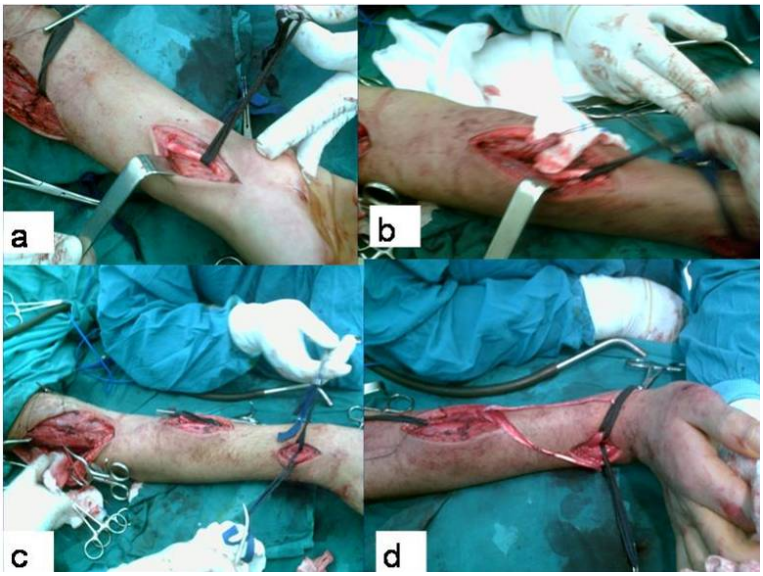
Bow-stringing of the rerouted extensor polloicis longus was not observed.

Grip strength

Average grip strength was 63% of that of the contralateral hand. Although 3 patients complained of weakness, difficulty with fine movement, flexion disturbances of the wrist and limited motion of the thumb, most patients were satisfied with their results.



Figures 1a-d: a. the position of the wrist and hand before surgery b. scar of compound fracture humerus. The radial nerve was entrapped inside the fracture c. The volar incision lines for transfer. D. The dorsal incision lines for tendon transfer



Figures 2 a-d: a. volar exposure of FCR b. Transfer of pronator teres to ECRbr c.Exposure of EPL and EDC d. The split FCR transfer to EPL and EDC

DISCUSSION

Tendon transfers have been used for radial nerve palsy for more than one century[6,9] when hope of spontaneous or surgical recovery appears to be unlikely. Nerve grafting may restore sensation and motor function but, even when this procedure is possible, the result is not always good enough to give complete extension of the wrist and digits[10]. Under such circumstances, tendon transfers are an alternative means of restoring good wrist and digital function. In discussing this item, the following issues have to be addressed: timing of surgery, tendon transfers to restore wrist extension, tendon transfers to restore finger extension, keeping thumb antepulsion and abduction, the split flexor carpi radialis transfer.

A delay of 6 months is recommended before transfers are carried out when there is a possibility of spontaneous nerve recovery because tendon transfers will never achieve the same finger extension as that following nerve recovery and are always partially dependent on the wrist tenodesis effect[10]. For patients older than 60 years, transfers can be carried out earlier because nerve grafting will not give as good a result as in younger patients and a prolongated wait can be detrimental to functional recovery after the transfer in this age group. In this series, the average period between primary nererve surgery and tendon transfer operation was 17months

The main problem for the surgeon is the choice of tendons to transfer. In a high radial nerve palsy, three tendons will usually be required to restore each one of three functions: extension of the wrist, extension of the fingers and extension–abduction of the thumb[9,11].

To achieve wrist extension, the PT transfer seems to be preferred by most authors[5,9,12-14]. This tendon has all the required qualities: its power is appropriate for radial wrist tendon reconstruction, the extension moment arm is optimal and pronation action is conserved by the action of the pronator quadratus muscle[15]. ECRB is the preferred tendon of attachment. Of ECRB, ECRL and ECU, ECRB is the strongest wrist extensor with the lowest radial deviation moment arm[9,15]. We have always restored ECRB function with separation of the adhesion between the ECRL and the ECRB tendons. In respect of the range of motion of the wrist, we recorded a wider range of wrist extension than flexion . Postoperatively, average wrist extension was 50° (20°–70°) and wrist flexion was 40° (20°–60°). This corresponds with the results obtained by other authors.

Using the FCR for finger extension, our results were as follows. Active extension of the metacarpophalangeal (MCP) joint of the middle finger was 30° measured with the wrist in neutral extension. Average finger extension was 30°. Both active extension of the fingers with the wrist in the extended position and active flexion of the wrist with the fingers in the flexed position were limited. Average hyperextension of the interphalangeal (IP) joint of the thumb was 5° while the average range of motion of the interphalangeal joint was 65°.

Tsuge[14] reported a range of 32°/28°using the FCR as the finger extension transfer and Bincaz et al.[12] reported a range of 44°/22° with the hand open using the FCU as the finger extension transfer. Those differences have no functional importance because a range of motion of 20°/20° is adequate for normal function[16]. This

asymmetry between flexion range and extension range might either be explained by the way the tension of the transfer is adjusted during surgery or by the tendon used for the finger extension transfer[17]. It was noted[17] that mean flexion was 41° for patients with FCR transfers but only 21° if the FCU was used for the finger extension transfer. The choice of tendon transfer is more difficult for reconstruction of the finger extensors, both in respect of the motor chosen and the tendons that must be reconstructed. Some authors consider it is necessary to reconstruct the EIP as well as the EDC[12]. The EDMin was also reconstructed[17] without any hyper-extension of this digit, as predicted by Tubiana[6]. To prevent this, the tension must be regulated to keep the fifth finger in a more flexed position during suturing, in order to maintain the natural cascade of finger extension at the metacarpophalangeal joints viz. extension of the index4middle4ring4little finger. Tubiana recommended that EDC of the little finger be reconstructed if the EDMin is absent[6]. The use of the middle and ring finger superficial flexors, described by Boyes[18], is the first choice motor of tendon transfer to extend the fingers. The intrinsic qualities of this transfer are excellent because these two tendons are stronger than the EDC and have a longer excursion, over and above the tenodesis effect. On the other hand, this transfer has consequences for wrist strength and autonomy of flexor function of the donor fingers. Computer workers, in whom the autonomy of the fingers must be optimal, would not be served well by this procedure. Kruft et al.[16] also felt that the postoperative rehabilitation is longer and more difficult with this transfer. Two others motor tendons are more widely used for restoration of finger extension, viz. the FCU and the FCR. The choice between these two tendons remains controversial[6,12,13,15,19]. FCU is the stronger flexor of the wrist. It is also stronger than the EDC and has the advantage of a longer excursion than FCR. These qualities are, however, offset by two consequences of deactivation of the FCU at the wrist, viz. radial deviation and loss of wrist strength. Bincaz et al.[12], who only used the FCU motor, reported a difference in this respect of 2.5 kg. In cases of low radial nerve palsy, it seems inadvisible to use the FCU because the innnervation of the radial wrist extensors is intact and this, in conjunction with deactivation of the FCU, may produce a significant radial deviation, even if the FCU
maintains an ulnar position in its new functional position[9,20].

The FCR is the preferred option as the motor for finger extension. Its excursion is equal to that of the EDC, with power only slightly inferior. Its use maintains the natural equilibrium of the wrist in both the frontal and the sagittal planes. Tsuge[14] also maintained that the more direct FCR route through the interosseous membrane avoided any angulation and was less liable to adherence than the FCU, routed around the ulnar border of the wrist. We noted two ulnar wrist deviations in our series. This is rarely described in the literature. One reason for these could certainly have been radial wrist weakness produced by the FCR transfer. The preference is to transfer the PL to the EPL, the latter having been rerouted radially from Lister's tubercle[17]. Bincaz et al.[12] showed that the Merle d'Aubigne procedure is another efficient solution. This technique uses two transfers to the thumb, viz. FCU transferred to EPL and PL transferred to EPB and APL. In this transfer, the EPL transfer

also motors finger extension, with loss of autonomy of the thumb and the fingers[9]. The advantage is, however, a differentiation between the motor function of extension and abduction of the thumb. In respect of abduction, a tenodesis of the APL to the BR, as described by Tsuge[14] was favoured[17]. This permits good abduction without using the motor of thumb extension.

Split FCR transfer was reported by Lim et al.[7]. These authors split the FCR to reconstruct both finger and thumb extension, so avoiding multiple motors. Actually, split abductor pollicis longus tendon and muscle have been used to restore the function of the thumb in cases of ruptured extensor pollicis longus[21]. The flexor pollicis longus has been split to provide stability at the interphalangeal joint of the thumb in patients with tetraplegia[22]. Most of the actions in the above transfers, however, are synergistic to the action of the muscle being split or act in conjunction with the other actions of the muscle to the digit that received the transfer. Manktelow and Zuker[23] observed that the gracilis has separately innervated motor territories that may contract independently. Parts of the gracilis were used for facial reanimation and Manktelow and Zuker also suggested splitting this muscle into functioning neuromuscular territories. Independent function in a split transfer of the flexor carpi ulnaris was reorted[24,25]. A muscle that is ideal for splitting would have the following characteristics. The tendon of insertion should have an aponeurosis that extends proximally within the muscle, which allows easy and accurate division in the intercompartmental plane up to the proximal limit, facilitating anatomic and functional separation of the compartments. It is also vital that the nerve and blood supplies to each compartment are independent. Bipennate muscles have this muscle form, and in the forearm, the flexor carpi ulnaris and FCR have been identified as good candidates for split muscle transfers[8,25]. Another criterion for split-muscle transfer is that the compartments should also have an adequate physiologic cross-sectional area and fibers length to ensure that they function effectively after transfer [26, 27, 28] In the case of the FCR, previous work has shown a separate nerve branch from the median nerve to each compartment of the FCR and also an adequate vascular supply to each compartment[8]. The muscle architecture has been previously reported to be adequate, with the physiologic crosssectional area and fiber length of the ulnar compartment of the FCR matching those of the extensor pollicis longus, and the physiologic cross-sectional area and fiber length of the radial compartment of the FCR matching those of the extensor digitorum communis[8,25] Splitting the FCR allowed Lim et al.[7] to perform the transfer in the absence of an adequately functioning palmaris longus. If present, the palmaris longus muscle may also be transferred to restore the function of the abductor pollicis longus for a more complete reconstruction of the thumb. Besides the reconstruction described here, a split FCR transfer may also be used in the group 5 tetraplegic patient[8]. Leaving the radial compartment *in situ* to preserve wrist flexion, the split ulnar compartment of the FCR could be used as a transfer alone to restore thumb opposition. This would provide a quantum improvement in hand function in these severely disabled patients when combined with an extensor carpi radialis longus transfer to the long finger flexors.

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carpi ulnaris muscle, as it is the most important muscle involved in hand grip. In his procedure, the pronator teres (PT) is transferred to the ECRB, the flexor carpi radialis (FCR) is transferred to the EDC through a window made in the interosseous membrane of the forearm. The palmaris longus (PL) is then transferred to the volarly rerouted extensor pollicis longus (EPL). The latter transfer might, however, lead to bowstringing of the transferred tendon[5], so that it loses its extensor function and is converted to a wrist abductor. For our part, extension of the fingers and of the thumb were restored with a split flexor carpi radialis (FCR)[7]. The insertion of the FCR tendon was divided and by applying tension to the cut end, the muscle was split into 2 compartments along the tendon and the aponeurosis all the way to its proximal fifth[8]. Care was taken not to divide the separate vascular and nerve pedicles entering each compartment. The smaller ulnar-sided tendon was passed radially and subcutaneously and woven into the extensor pollicis longus tendon while the radial tendon was passed dorsally and woven into the tendons of the extensor digitorum communis. In order to restore thumb abduction, the palmaris longus (PL) was sutured to the abductor pollicis longus (APL) in three patients at a second stage.

CONCLUSION

Pronator teres transfer to extensor carpi radialis brevis restores wrist extension efficiently; the split flexor carpi radialis transfer to extensor pollicis longus and extensor digitorum restores function separately to each muscle. No tendon bowstringing occurs. To enhance thumb abduction, the transfer may be augmented in certain cases with Palmaris longus to abductor pollicis longus transfer.

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