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TECHNIQUE

Management of Hand Palsies in Isolated C7 to T1 or C8, T1 Root Avulsions

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ABSTRACT

Thirteen patients were operated on for hand palsies in cases of C7 to T1 or C8, T1 root avulsions. Finger flexion and intrinsic function were paralyzed in all patients. Finger extension was paralyzed in 12 patients. Wrist flexion and extension were present in all patients. Tendon transfers were performed to restore the different functions.

The extensor carpi radialis longus was transferred to the flexor digitorum profundus. The brachioradialis tendon was transferred to the flexor pollicis longus tendon for thumb flexion, with a tendon translocation procedure in 6 patients. Intrinsic function was reanimated with passive capsulorrhaphy techniques or other equivalent techniques in 9 patients. Extensor tenodesis was performed to restore hand opening with active wrist flexion in all patients. Moreover, sensory neurotization was performed to restore sensation on the ulnar side of the hand. All patients recovered finger flexion with an average pulp-to-palm distance of 2 cm. Finger extension occurred in 30 degrees wrist flexion. The average Kapandji score was 3. Key pinch was present in all patients. The average grip strength was 8 kg; the average key pinch was 5 kg. All patients recovered a protective sensation with a mean time of 19.5 months.

Injury with C7 to T1 or C8, T1 root avulsions is a rare entity. Motor nerve surgery is not possible in these cases. However, surgery remains a challenge and may greatly improve these patients. Therefore, we propose a new tendon transfer and sensory neurotization protocol.
Keywords: brachial plexus, hand palsy, tendon transfer, sensory neurotization

HISTORICAL BACKGROUND

Avulsion of C7 to T1 or C8, T1 roots is a rare entity in brachial plexus lesions, representing about 3% of all brachial plexus injuries.[1] In these lesions, motor and sensory deficits are far from the localization of nerve lesions, spontaneous recovery is not possible. Therefore, only tendon transfers are generally indicated. Some microsurgical techniques have been described to improve hand function after total brachial plexus palsy.[2–6] However, only a few publications have described surgical treatments in case of C7 to T1 or C8, T1 root avulsions with short series.[7–10] In these reports, many patients had partial or complete brachial plexus injuries, therefore, in these cases, strategy is difficult to understand. The purpose of this case series was to present a clear surgical strategy to restore a more functional hand in C7 to T1 or C8, T1 avulsion. The results of 11 patients are presented.

INDICATIONS/CONTRAINDICATIONS

This surgical management is proposed in hand palsies after C7 to T1 or C8 and T1 root injuries. Clinical presentation is a paralytic hand with intrinsic muscles and complete finger palsies. Wrist extension and flexion are generally present. The finger flexion is not possible, and finger extension is sometimes preserved if C7 is not injured.

This surgery is not performed if they are forearm muscles injuries. Forearm muscles must be preserved to perform tendon transfers.

TECHNIQUE

Surgery is administered with the patient under general anesthesia. The wrist and hand is then placed supine on the operating table. The extremity is exsanguinated, and a tourniquet is inflated to greater than 100 mm Hg above systolic blood pressure. The ipsilateral lower limb is prepared to harvest the nerve graft (sural nerve). The surgical steps are generally performed at the same time to correct the different palsies.

A 10-cm incision is performed both on the volar and lateral aspects of the wrist. The brachioradialis (BR), the flexor digitorum profundus (FDP), the flexor digitorum superficialis (FDS), the flexor pollicis longus (FPL), and the median nerve are identified.

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Flexor Pollicis Longus Palsy

The BR and the FPL tendon are easily isolated. Care must be taken to avoid damage to the radial nerve. The distal insertion of the BR is detached from the radius and released until the third proximal part of the insertion on radius. At least 2.5 to 3 cm of passive excursion of the BR tendon must be obtained from the resting position. When the BR is perfectly released, the tendon is transferred to the FPL tendon without any traction to avoid fixed flexion of an interphalangeal (IP) joint (Fig. 1). An end-to-side anastomosis with Pulvertaft suture is performed. Tension must be sufficient so that the thumb reaches the long finger in 20 degrees of passive extension.

To increase abduction and pronation of the thumb during IP flexion, the FPL tendon may be translocated through an IP arthrodesis (modified Makin procedure[11,12]). After a dorsal incision on the thumb, the IP joint is opened (Fig. 2). The FPL tendon is then released and placed on the dorsal aspect of the first phalange. The IP arthrodesis is then fixed with 2 Kirschner wires after cartilage resection.

Flexor Digitorum Profundus Palsy

Through the same volar and lateral approach, the extensor carpi radialis longus (ECRL) tendon is located and divided from its bone attachment. The FDP tendons are exposed and sutured together. The ECRL tendon is then rerouted along the lateral side of the radius and sutured to the FDP tendons with a strong Pulvertaft procedure (Fig. 1). In wrist extension, the fingers must be semiflexed.

Metacarpal Joint Extension Palsy

Extensor digitorum communis (EDC) tenodesis is performed if finger extension is not present. The EDC tendons may be fixed to the radius with transosseous sutures. To avoid lengthening or rupture of this tenodesis, we now prefer to suture EDC tendons to FDS tendons. This fixation is performed through the interosseous membrane.[13] A dorsal longitudinal approach to the wrist is performed. The dorsal retinaculum is divided on the fourth extensor compartment. Extensor tendons are retracted to expose the interosseous membrane. Interosseous membrane is detached to reach the anterior compartment of the forearm. Hemostasis of the anterior interosseous artery is then performed. The FDS tendons (repaired with the anterior approach) are then pulled through the interosseous membrane from the anterior compartment to perform the tenodesis. During traction on the FDS tendons, care is taken to avoid the median nerve. The EDC tendons are then sutured side-to-side to the FDS tendons with nonabsorbable sutures. Tendons are tensed to have metacarpal (MCP) joints in extension when wrist is in neutral position. When sutures are placed, the tenodesis effect may be tested during the procedure: MCP joint extension occurs in 30 degrees of passive wrist flexion. The dorsal extensor retinaculum is then closed.

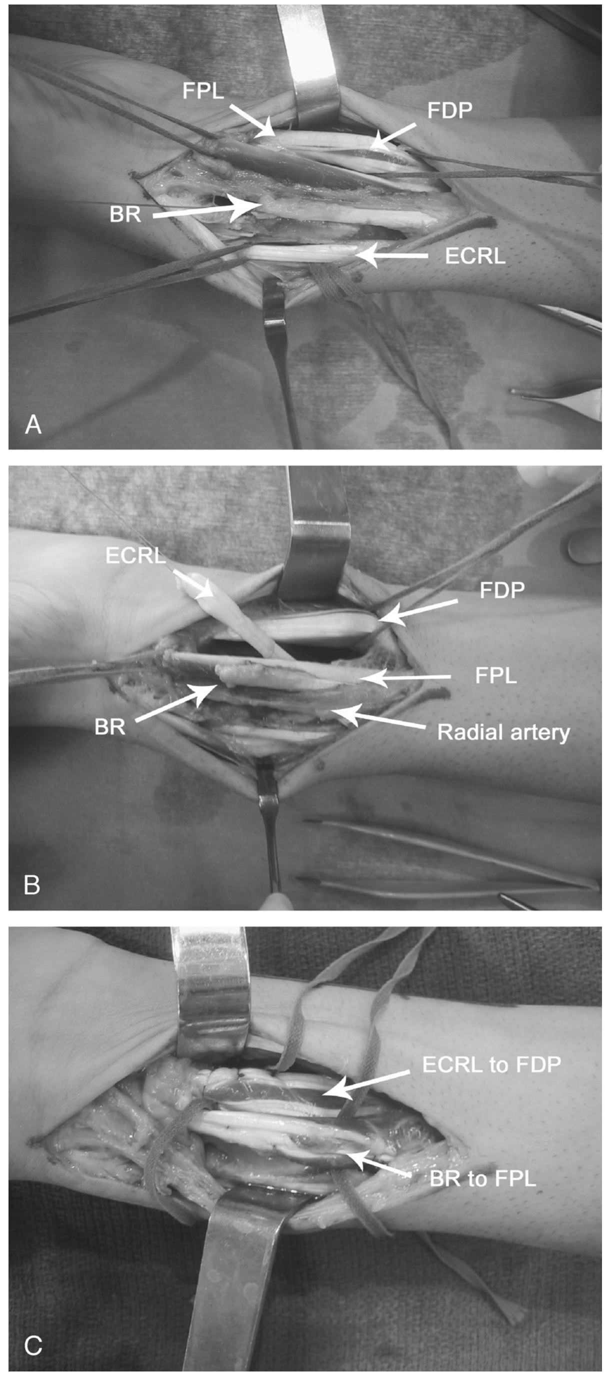

FIGURE 1. A, Volar and lateral approach to isolate the ECRL tendon, the BR tendon, the FDS tendons, the FPL tendon, and the FDP tendons. B, The ECRL and BR tendons are passed under the radial pedicle to reach the FPD and FPL tendons, respectively. C, Strong Pulvertaft sutures are placed to avoid tendon lengthening.

The extensor pollicis brevis (EPB) and abductor pollicis longus tenodesis was performed by suturing the

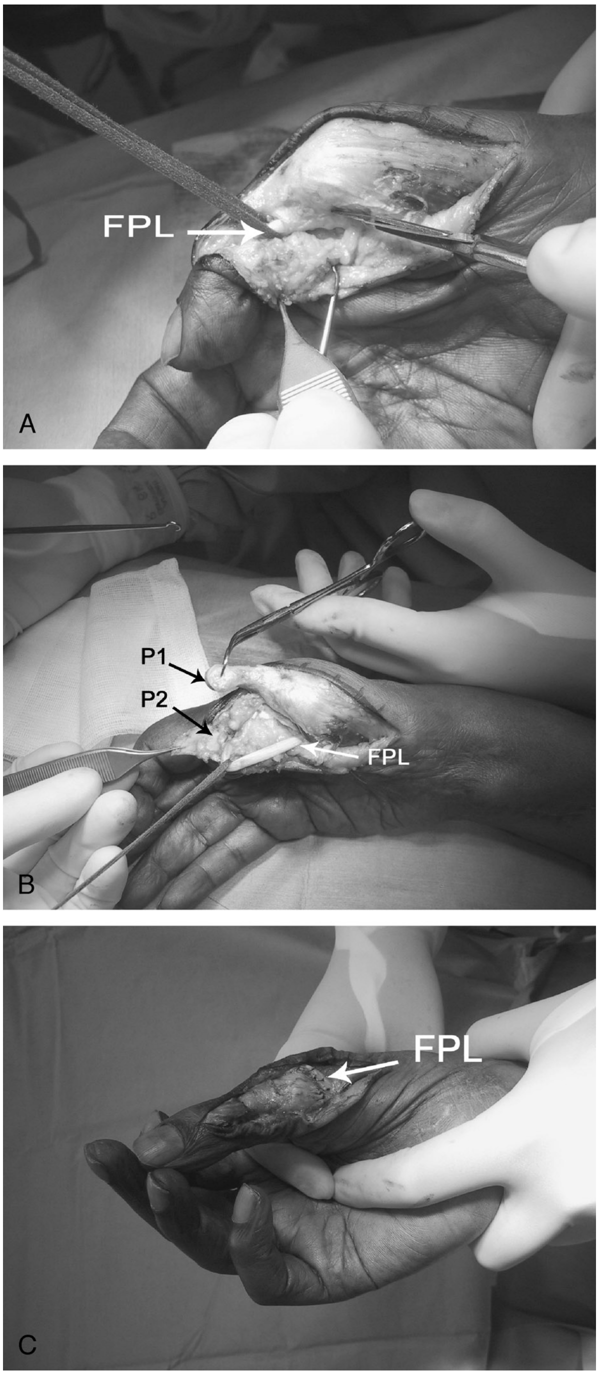

FIGURE 2. Modified Makin procedure. A, The FPL tendon is isolated and released. B, The thumb IP joint is opened to translocate the FPL tendon. P1 indicates proximal phalangeal; P2, distal phalangeal. C, The FPL tendon is translocated. The level of the reflection of the translocated tendon should necessarily be the neck of the first metacarpal bone. Operative testing in passive wrist extension: pulp-to-pulp contact between thumb and fourth finger is possible.

tendons on the dorsal retinaculum first compartment. Through the same approach, the first compartment of the dorsal retinaculum is located. The abductor pollicis longus and extensor pollicis brevis tendons are isolated and sutured to the dorsal retinaculum. In 30 degrees of wrist flexion, the thumb and long fingers must be in full extension.

Interosseous Palsy

No transfer procedures were used to recover proximal interphalangeal extension with metacarpophalangeal (MP) flexion. We performed a tenodesis suturing the FDS tendon on A1 pulley according the technique of Chevallard.[14] A palmar incision was performed in the distal palmar crease. The A1 pulleys of long fingers were exposed. The FDS tendons were then isolated and sutured to the A1 pulleys (nonabsorbable sutures) for each finger with 30 degrees of MP flexion.

Sensory Deficit of Ulnar Side of the Hand

Neurotization of the lateral antebrachial cutaneous nerve to the cutaneous dorsal branch of the ulnar nerve is performed (Fig. 3).[15]

The lateral antebrachial cutaneous nerve is located through a 3-cm incision on the volar aspect of the forearm. A volar incision is performed on the medial side of the wrist. The flexor ulnaris tendon is retracted to expose the ulnar nerve. The dorsal branch of the ulnar nerve is then isolated and divided just after the division from the ulnar nerve. The dorsal branch is then released and recovered through the wrist dorsal incision.

The sural nerve is harvested from the ipsilateral lower limb. The sural nerve is divided and placed under the skin between the dorsal branch of the ulnar nerve and the lateral antebrachial nerve. The distance between the extremities of the dorsal branch and the lateral antebrachial nerve measured generally about 15 cm. An epiperineural anastomosis is then performed (with microscope and 10/0 nonabsorbable sutures) between

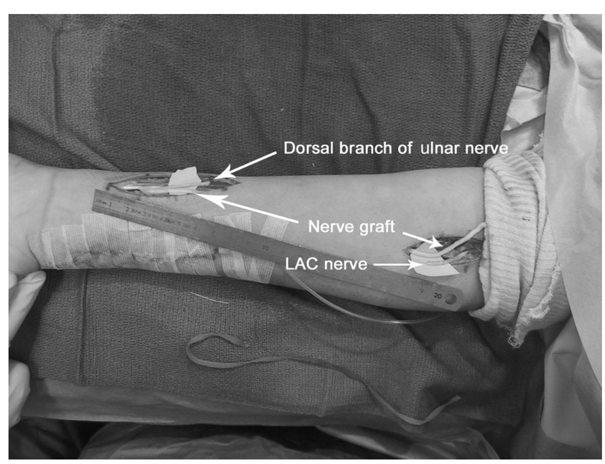

FIGURE 3. Sensory neurotization between the lateral antebrachial cutaneous (LAC) nerve (terminal branch of musculocutaneous nerve) and the dorsal branch of the ulnar nerve.

the dorsal branch of the ulnar nerve and the lateral antebrachial nerve using the sural nerve graft.

A suction drain is placed in the anterior forearm compartment to avoid hematomas, and the skin is closed with 4.0 polypropylene sutures.

COMPLICATIONS

Early complications after this technique may include wound infection, hematoma, and nerve injury (median nerve). Therefore, median nerve and the FDS tendons are isolated during the volar approach. Late complications may include tenodesis lengthening, tendon rupture, and joint stiffness.

REHABILITATION

The wrist is immobilized in neutral position with MCP and proximal interphalangeal joints in extension, for 3 weeks, in a noncircumferential short arm splint. After 3 weeks, rehabilitation is started with a physiotherapist. Active finger flexion and thumb pronation are performed, and active wrist flexion is encouraged to obtain passive finger extension. Strengthening and heavy lifting are not begun before 12 weeks.

RESULTS

Thirteen patients with C7 to T1 or C8, T1 root avulsions were treated. There was 1 woman and 12 men. The average age was 27 years (range, 20–37 years). Brachial plexus palsy occurred in motor vehicle accidents in 5 patients and in motorcycle accidents in 8 patients.

All patients had normal shoulder and elbow active ranger of motion. Twelve patients had Horner sign. Concerning hand function, finger flexion and intrinsic function were not present in all patients. Metacarpal joint extension was present in 1 patient. Wrist flexion (flexor carpi radialis), pronation (pronator teres), and extension (extensor carpi radialis longus and brevis) were present in all patients. All patients had a sensory defect of the ulnar aspect of the hand. Myelography was performed in all patients. Root avulsions were noticed with pseudomeningoceles of C8 and T1 roots in all patients. The C7 root was injured in 9 patients.

The mean follow-up was 38.5 months (range, 24 to 62 months).

Range of Motion

Active long finger flexion was recovered in all patients with 2-cm average pulp-to-palm distance (range, 0–4.5 cm). Active IP flexion of the thumb was recovered in 5 patients. The other 5 patients (Makin procedure through an IP arthrodesis) had an active MCP flexion. The average Kapandji score was 3 (range, 1–6). Key pinch was present in all patients.

Finger extension was achieved in all patients. The average angle of wrist flexion to obtain finger extension was 40 degrees (range, 20–60 degrees). The average distance between thumb and finger pulps during maximum opening was 6 cm (range, 2–12 cm).

Strength

The average grip strength was 8 kg (range, 3–12 kg). The average key pinch was 5 kg (range, 2–10 kg).

Sensory Recovery

The sensory aspect of the ulnar side of the hand was recovered in all patients. However, the sensory recovery was not complete (S2). The mean time of recovery was 19.5 months (range, 16–25 months).

No complications were described such as infection or reflex sympathetic dystrophy. Two patients had a progressive lost of MP joint extension (EDC tenodesis fixed to the radius). However, they did not want further surgery.

DISCUSSION

In case of C7 to T1 or C8, T1 root avulsions, motor nerve graft surgery is not possible.[7] Therefore, tendon transfers have an important place in these hand palsies.[7–9] Different functions have to be recovered in these hand palsies: finger flexion and extension, intrinsic function, and sensory aspect of the ulnar side of the hand.

For finger flexion, most of the authors have reported doing a transfer of the ECRL to the FDC tendons.[7–9] This transfer allows recovering finger flexion with a small pulp-to-palm distance and with sufficient strength. Some authors performed this transfer through the interosseous membrane.[7,8] However, we already used the interosseous space to perform the extensor tenodesis. Moreover, active tendon transfers passed through the interosseous membrane may be limited with pronation motion, present in C7 to T1 root injuries. In our technique, the transfer is passed from the dorsal to the volar side around the radius.

Wrist extension never decreases after ECRL tendon harvest because the extensor carpi radialis brevis muscle was strong in all patients. We sutured all the FPD tendons together to improve grasp strength. However, the ECRL tendon may be transferred to the FDP of the index finger to improve tip pinch.[9] We consider that the restoration of a strong grasp and key pinch is more important than an isolated tip pinch in these hand palsies. As a matter of fact, precise movement may be performed with the normal contralateral side. Microsurgical transfers have been described to restore finger flexion in lower brachial plexus injury.[16] However, even if finger flexion is restored, strength has to be assessed. In our series, the average grasp was 8 kg. Takka et al[6] showed that the average strength in finger flexion after microsurgical transfer was 1.3 kg. Even if strength was assessed in complete brachial plexus injuries, reinnervated muscle is weaker than a normal transferred muscle.[17,18] Moreover, even if microsurgical sutures are placed by trained surgeons, failures caused by microsurgical sutures are possible.

Concerning intrinsic function, active restoration of interosseous muscles cannot be easily performed. In our first patients, no intrinsic function reanimations were performed. These patients recovered a strong hook finger flexion and key grip. However, pulp-to-pulp pinch was not possible. Therefore, we currently stabilized MP joints with capsulorrhaphy, passive lasso procedure, or equivalent.[19] We currently prefer suturing FDS tendons on A1 pulley.[14] It seems more resistant than capsulorrhaphy, and lengthening has not been described in our experience.

Thumb flexion can be restored with BR transfer.[7–9] However, contrary to other authors, we performed a translocation of the FPL through an IP arthrodesis to avoid thumb-in-palm positions and improve contact between thumb and long fingers.[11,12]

Sensory deficit of the ulnar aspect of the hand results in burns or wounds. Therefore, we performed a sensory neurotization of the antebrachial lateral nerve to the dorsal branch of the ulnar nerve.[15] We have no failure in our series; however, patients never recovered more than S2. Nevertheless, this sensory level is sufficient to protect against burns or wounds. Our technique is easier than sensory transfer from the intercostal nerve described by Doi et al.[16] Moreover, the distance between donor nerve and skin territory, thus time of sensory recovery, is shorter with our technique.

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