Median to Radial Nerve Transfers for Management of Radial Nerve Palsy

Abdelsalam Eid Abdelsalam[1], Amr Alsayed Ali[2], Ahmed Mashhour Gaber[1], Mohamed Adel Kamal Abdeen [1]

1 Orthopedic Surgery Department, Faculty of Medicine, Zagazig University, Egypt

2 Orthopedic Surgery Department, Faculty of Medicine, Assuit University, Egypt

Email: ma.abdeen@medicine.zu.edu.eg, mohamed.adel.abdeen2023@gmail.com

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Abstract

Background: Radial nerve injury results in loss of wrist, finger, and thumb extension. Traditionally, radial nerve palsies that fail to recover spontaneously have been reconstructed with tendon transfers or nerve grafts. Nerve transfers are a novel approach to the surgical management of Sunderland grade IV and V radial nerve injuries. We describe our technique for median to radial nerve transfers. In this procedure, the flexor digitorum superficialis nerve is transferred to the extensor carpi radialis brevis nerve for wrist extension, and the flexor carpi radialis nerve is transferred to the posterior interosseous nerve for finger and thumb extension. Our experience with these nerve transfers has demonstrated excellent outcomes up to 10 months after injury. Indeed, unlike tendon transfers, median to radial nerve transfers have the potential to restore normal radial nerve function, including independent finger motion. Tension-free nerve coaptation and postoperative motor re-education are critical factors to achieving these successful outcomes

Keywords: Radial Nerve Transfers, Radial Nerve Palsy

Introduction

HE RADIAL NERVE is one of the most commonly injured peripheral nerves.1 When spontaneous recovery has not occurred or is not expected to occur, radial nerve function has been traditionally restored with tendon transfers. In fact, radial nerve tendon transfers for wrist and finger extension are among the most successful tendon transfers in the hand surgeon's armamentarium. However, tendon transfers require good passive range of motion and have several disadvantages, which include extensive muscle dissection, altered muscle biomechanics, prolonged immobilization, donor deficit, potential for tendon rupture and adhesions, and subnormal functional return.2–5 Nerve transfer is an alternative reconstructive technique, which, by reinnervating native musculature, circumvents many of these challenges and offers the potential for greater functional return. Specifically, nerve transfers for restoration of radial nerve function can allow for independent finger extension and simultaneous, full wrist and finger extension.6 We present our patient evaluation and surgical technique for median to radial nerve transfers. Median nerve branches are ideal donors for the radial nerve, owing to their expendability, synergism, and close proximity in the forearm. Our preferred nerve transfers include flexor digitorum superficialis (FDS) nerve to extensor carpi radialis brevis (ECRB) nerve for wrist extension, and flexor carpi radialis (FCR) nerve to posterior interosseous nerve (PIN) for finger and thumb extension

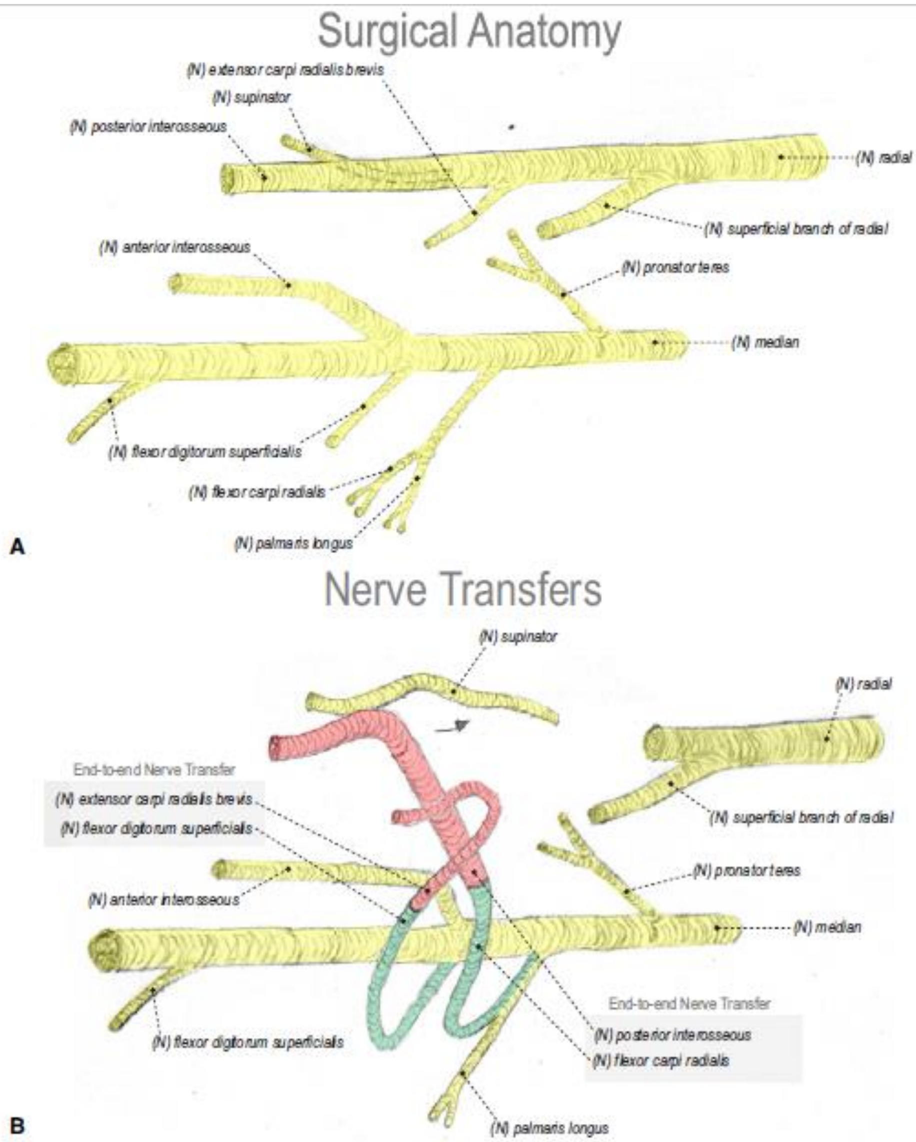

FIGURE 1: Illustrative anatomy for the median to radial nerve transfer. **A** At this location, the radial nerve has 3 primary nerve branches: RSN, ECRB, and PIN. The supinator branch is located deep to the PIN and courses deep into the supinator for innervation. The median nerve has several nerve branches, which include the PT, FCR/PL, AIN, and 2 FDS branches. **B** Two nerve transfers occur in the median to radial nerve transfer for restoration of wrist/finger extension. The donors (green) and recipients (red) occur in the following specific sets for optimal results with postoperative rehabilitation: 1) FCR nerve to PIN and 2) FDS nerve to ECRB. PIN and FDS are antagonistic.

PATIENT EVALUATION All patients are evaluated with history, physical examination, and electrophysiologic studies. The mechanism, location, timing, and degree of radial nerve injury are determined, and serial clinical examinations and EMG are used to evaluate for presence or absence of spontaneous radial nerve recovery. A careful examination of median and ulnar nerve function is also performed, with specific attention to donor nerve integrity. Ideally, donor FCR and FDS muscles should have a minimum Medical Research Council grade 4 strength. As well, strength of the flexor carpi ulnaris and median and ulnar-innervated flexor digitorum profundi is assessed, as these will maintain finger and wrist flexion following donor nerve harvest. Patient goals and expectations are explored to help determine appropriateness of nerve versus tendon transfers to restore radial nerve function. PATIENT SELECTION Patients with high radial nerve injuries that show no evidence of spontaneous recovery, either clinically or on EMG (ie, absence of motor unit potentials), by 3 to 4 months from injury are indicated for median to radial nerve transfers. In other words, eligible patients demonstrate a Sunderland grade IV or V axonal injury to the radial nerve in the arm. This procedure is designed to restore function to the wrist, finger, and thumb extensors but does not target the triceps, brachioradialis (BR), or extensor carpi radialis longus (ECRL) muscles. Patients must have intact extrinsic median nerve function, and median nerve branches to the FCR and FDS must be expendable in the global context of the patient's upper extremity injury. We have had success with median to radial nerve transfers up to 10 months after injury.6 Patients who present more than 10 months from injury or who have a direct injury to the PIN and/or ECRB branch are not good candidates for this nerve transfer procedure and may be better served by traditional tendon transfers. In addition, patients who are unwilling or unable to wait several months to allow for reinnervation of wrist and finger extensors via the median to radial nerve transfer approach may be more suited to tendon transfer procedures or nonsurgical management. However, in patients with stiff and swollen hands, nerve transfers are a better option than tendon transfers, because postoperative immobilization is minimal and hand therapy may continue throughout the postoperative course.

TABLE 1. Surgical Steps for Median to Radial Nerve Transfers (FDS to ECRB, FCR to PIN)
Step 1. Mark a lazy-S incision in the proximal **forearm** extending to the mid-**forearm** (extend more distal if performing PT to ECRB tendon transfer).
Step 2. Expose and decompress the median nerve through the following steps: **A.** Identify the superficial head of the PT between the radial vessels and RSN (ie, *radial to the vessels*) **B.** Step-lengthen the PT tendon (If performing tendon transfer: Completely elevate the PT tendon with strip of periosteum) **C.** Identify the median nerve *ulnar to the radial vessels,* intimate with the radial/deep surface of the superficial head of PT **D.** Release the deep head of the PT **E.** Divide the tendinous leading edge of FDS
Step 3. Identify the branches of the median nerve, and confirm with a nerve stimulator (within 30 minutes if using a tourniquet): • FCR and PL nerves: medial/deep aspect of median nerve • FDS nerves: medial aspect of the median nerve, distal to FCR/PL branches • PT nerve: the most superficial, proximal branch of the median nerve • AIN: lies on the lateral side of the median nerve
Step 4. Dissect the donor nerve branches, FCR and FDS, as distally as possible, and tag with a vessel loop.
Step 5. Expose and decompress the radial nerve through the following steps: **A.** Identify the radial sensory nerve on the undersurface of the BR muscle **B.** Follow the radial sensory nerve proximally to the main radial nerve just distal to the elbow **C.** Release the tendinous leading edge of the ECRB transversely **D.** Divide the tendinous leading edge of the supinator (**arcade of Frohse**) and decompress the PIN
Step 6. Identify the branches of the radial nerve and confirm there is no function with a nerve stimulator: • ECRB nerve (small): lies radial and parallel to the radial sensory nerve • PIN (large): lies radial to the ECRB nerve and heads in a posterior direction deep to supinator • Supinator nerve: arises from deep surface of PIN, and is excluded from transfer
Step 7. Follow the mantra "**donor distal, recipient proximal**" • First, divide the donor nerves (FCR and FDS) distally • Second, dissect and divide the recipient nerve branches, ECRB and PIN, as proximally as possible (to above elbow crease) • The usual overlap of donor and recipient nerves is 6–7 cm
Step 8. Coapt the FDS nerve to the ECRB nerve with 9-0 nylon suture +/− fibrin glue
Step 9. Coapt the FCR nerve to the PIN nerve with 9-0 nylon suture +/− fibrin glue
Step 10. If desired, perform the LABC nerve to RSN transfer and coaptation
Step 11. Ensure tension-free nerve coaptations in all ranges of motion of the arm and forearm
Step 12. If performing, complete the PT to ECRB tendon transfer with a Pulvertaft weave

SURGICAL TECHNIQUE Table 1 outlines the surgical steps for median to radial nerve transfers We prefer to use a tourniquet for this procedure. However, this requires the surgeon to expose and identify median and radial nerve branches quickly (within approximately 30 – 40 minutes), so that donor and recipient nerves do not become refractory to stimulation from tourniquet-induced neuropraxia. For surgeons who are new to this procedure, it is likely best to avoid using a tourniquet until comfort with the anatomy and procedure are achieved. Exposure and decompression of the median nerve A single, lazy-S incision is made in the volar forearm, starting proximally at the lateral edge of the antecubital fossa and continuing distally to the mid-forearm (Fig. 2). Dissection is carried down through the subcutaneous tissue and fascia, taking care to avoid branches of the lateral antebrachial cutaneous (LABC) nerve, which accompanies the cephalic or accessory cephalic vein (Fig. 3). The superficial head of pronator teres (PT) is then identified. An easy method to quickly locate the PT tendon is to look between the radial sensory nerve (RSN) laterally and the radial vessels medially in the mid-forearm (Fig. 4). A step-lengthening of the PT tendon is performed to release the superficial head and to allow adequate exposure of the median nerve in the proximal forearm (Fig. 5). Alternatively, a PT tendon transfer can be performed at the same time as the median to radial nerve transfers to provide an early internal splint for wrist extension. In this case, the step-lengthening is not performed, but rather, the distal attachment of the PT tendon is elevated along with an extension of periosteum, and the entire superficial head of PT is reflected medially to expose the median nerve as described earlier. To harvest this strip of periosteum, the incision must be extended distally onto the radial aspect of the volar forearm. This will allow adequate exposure of the distal attachment of the PT tendon (Fig. 6). The periosteum is then elevated from distal to proximal using a freer elevator, allowing for the mobilization of the superficial head of PT (Fig. 7). The recipient ECRB tendon is identified distally, radial to the BR and extensor carpi radialis longus tendons, through this incision (Fig. 8). Following either the PT step-lengthening or PT elevation for tendon transfer, the dissection moves proximally to locate the median nerve medial to the radial vessels, intimate with the flexor/pronator muscle belly. It is usually fairly hidden and deep. To expose the median nerve, the deep head of PT is identified and fully released (Fig. 9). This release can involve a tendinous arch of the deep head of PT that is circumferential to the median nerve. This is typically seen in cases with median nerve compression in the forearm for PT syndrome. Following the release of the deep head of PT, the median nerve is traced distally, and the tendinous arch of the FDS muscle is released, again similar to the decompression of the median nerve in the forearm (Fig. 10). These steps allow enough of the median nerve to be exposed to identify all the major branches necessary for the transfer. Identification of median nerve branches The median nerve is exposed to identify the following donor components (Figs. 1A, 11). The most proximal branch of the median nerve in the forearm is the PT branch. This branch is found on the superficial (anterior) surface of the nerve and quickly divides into 2 distinct branches before entering the muscle. On the deep ulnar (medial) side of the median nerve, branches to the palmaris longus (PL) and FCR are encountered. The FDS branches separate from the median nerve distal to the PL/FCR branches. The large-caliber anterior interosseous nerve (AIN) is found on the radial (lateral) aspect of the median nerve. Internal neurolysis is not necessary to identify these branches, as they are all distinct from the median nerve proper.7 Electrical stimulation with a hand-held stimulation device is used to confirm the identity of the branches as they are tagged with vessel loops for later use.

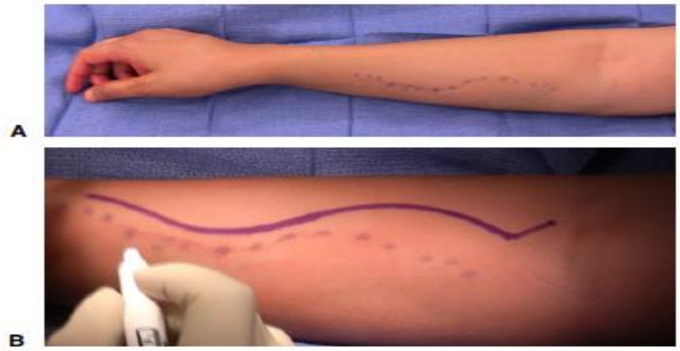

FIGURE 2: Orientation and incision for median to radial nerve transfer. A lazy-S incision is made over the proximal volar forearm, starting in the antecubital fossa and extending half the distance to the wrist crease over the medial border of the brachioradialis. The incision has been lengthened distally to mobilize the PT tendon for transfer to the ECRB tendon. **A** Orientation image and dotted markings for an unused incision. **B** Actual incision is visualized.

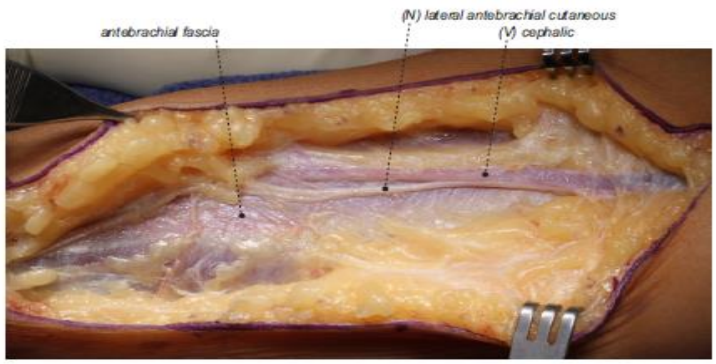

FIGURE 3: Exposure and identification of the LABC nerve. Upon exposure, the LABC is identified to accompany the cephalic or accessory cephalic vein. These structures are protected as dissection continues through the antebrachial fascia.

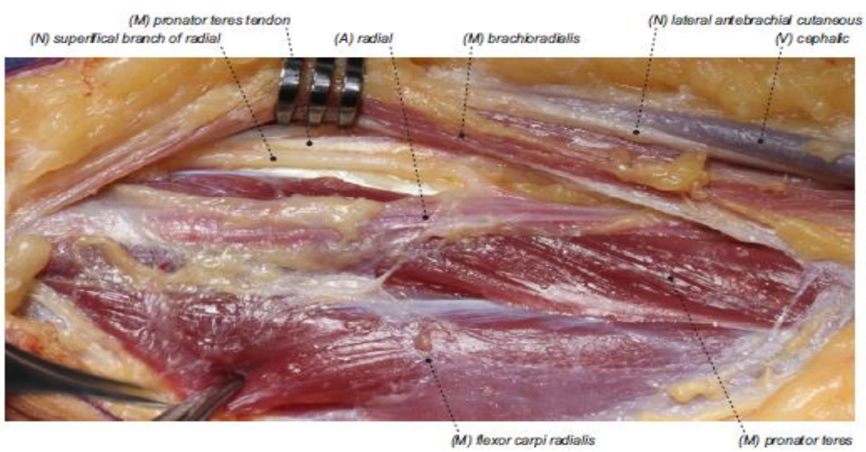

FIGURE 4: Landmarks for identifying the tendon of the superficial head of PT. By retracting the brachioradialis laterally, the RSN is identified lateral to the radial vessels. The tendon of the superficial head of PT is found lateral to the radial vessels and medial to the RSN.

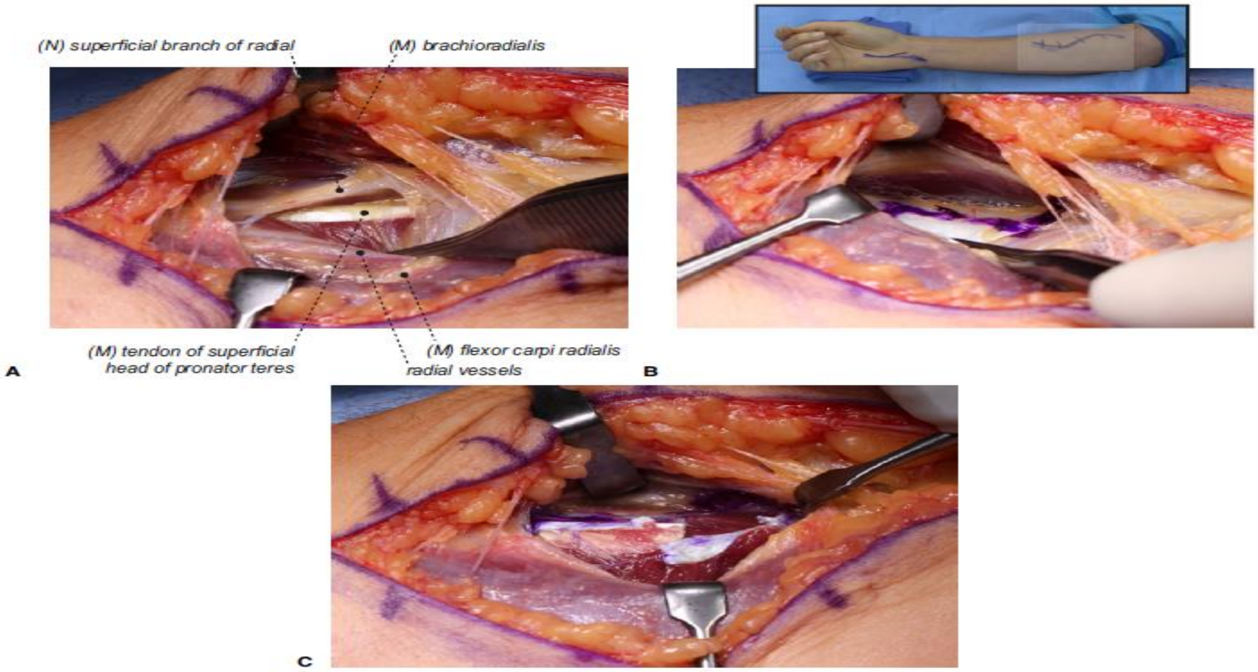

FIGURE 5: Step-lengthening of the superficial head of PT. **A** The tendon of the superficial head of the PT is easily identified between the RSN and the radial vessels. **B** A step-lengthening tenotomy in the PT tendon is performed. The deeper step in the tenotomy is made proximally, where it is easier to visualize. The more superficial step is made more distally. **C** After the step lengthening is made in the tendon, a substantial release on the whole pronator muscle will be achieved. In this figure, the length obtained by this tenotomy is easily seen as between 1 and 2 cm.

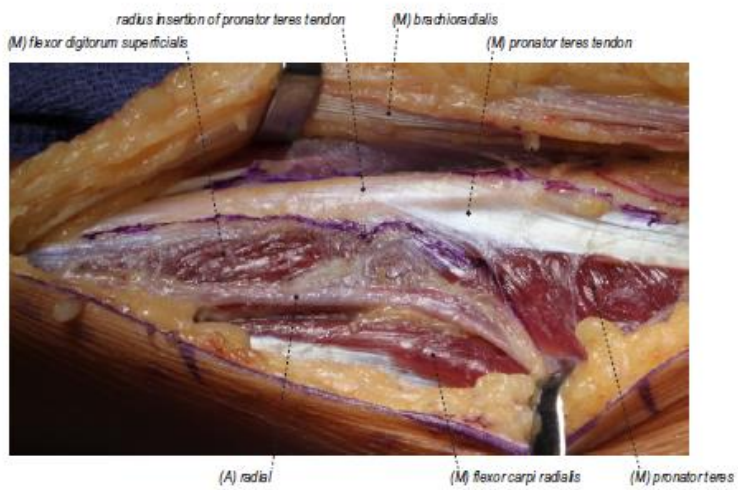

FIGURE 6: PT to ECRB tendon transfer (alternative to step-lengthening the PT). The PT tendon is marked in purple to mobilize and release it from the radius for the PT to ECRB tendon transfer. If this tendon transfer is not performed, the PT tendon is step-lengthened to allow for the proximal exposure of the median nerve, as in Figure 5.

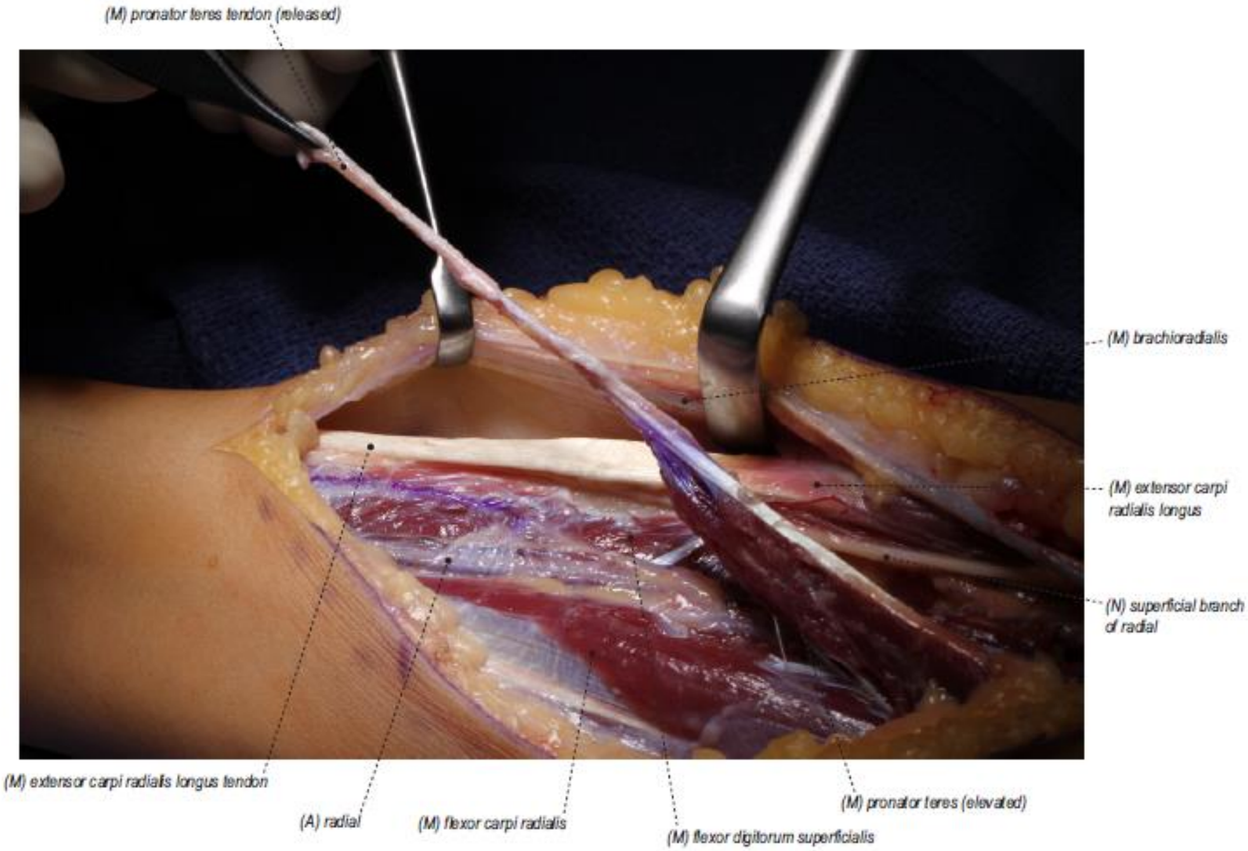

FIGURE 7: Release of the PT tendon from the radius for PT to ECRB tendon transfer. The PT tendon is released from its insertion to the radius and mobilized for the PT to ECRB tendon transfer.

Exposure and decompression of the radial nerve Through the same incision, the RSN is identified directly under the BR muscle. The BR is retracted laterally, and the RSN is followed proximally to the main trunk of the radial nerve. To expose the PIN and branch to ECRB, the tendinous origin of the ECRB muscle and the crossing vessels comprising the vascular leash of Henry are divided. These steps are similar to those for performing a PIN decompression. The radial nerve is then dissected as proximal as possible, under direct visualization. The mobilization of the PIN allows for a tension-free repair (without need for nerve grafts) and releases a secondary compression point that could impede nerve regeneration.8–9 The PIN and ECRB branches are stimulated with a hand-held device to confirm that no motor response is seen before proceeding with nerve transfer. The small-diameter ECRB branch is located radial to the sensory branch and is parallel to it. The largercaliber PIN is located radial to the ECRB branch and travels dorsally in a more oblique direction under the supinator. The branch to the supinator can be found exiting the posterior (deep) surface of the PIN and is excluded from the transfer. The PIN is then decompressed distally by releasing the tendinous leading edge of the ECRB and the supinator (arcade of Frohse). Transfer and coaptation of donor and recipient nerves The mantra “donor distal, recipient proximal” is key to a satisfactory, tension-free repair. The donor nerve branches, FCR and FDS, are traced as distally as possible into the muscle bellies until further branching is encountered. All FDS branches are usually harvested to maximize the number of axons transferred to the ECRB nerve for wrist extension. The donor FCR and FDS branches are then transected distally. The PL fascicle is generally not harvested, as we prefer to leave the PL muscle innervated so that a salvage PL to extensor pollicis longus tendon transfer can be performed, if needed.

The recipient nerve branches, PIN and ECRB, are then divided as proximally as possible. We prefer to neurolyse and exclude the branch to the supinator from the main trunk of the PIN for 3 reasons: 1) it allows for more aggressive mobilization of the PIN, 2) exclusion of the supinator branch allows all transferred axons to be directed to finger and wrist extension,10 and, 3) functional loss from exclusion of the supinator branch is minimal because the biceps muscle (when functional) provides strong and effective supination. The recipient nerves are then transposed medially. We frequently run the recipient nerves below the radial vessels to follow the shortest path toward the median nerve branches The usual overlap of donor and recipient nerves is approximately 6 –7 cm; this redundancy ensures a tension-free coaptation. The FCR and FDS nerves are coapted to the recipient PIN and ECRB branches, respectively, with 9 – 0 nylon sutures under the microscope. We frequently use fibrin glue in addition to sutures to seal the coaptation. An LABC to RSN transfer can also be performed at the same time as the motor nerve transfers to restore sensation to the dorsal hand. These coaptations should be completely tension free through the full range of motion of the elbow and forearm. If a tourniquet is used, we prefer to release the tourniquet and achieve hemostasis after transfer of donor and recipient nerves but before coaptation. Particular attention should be paid to hemostasis in the vicinity of the vascular leash of Henry.

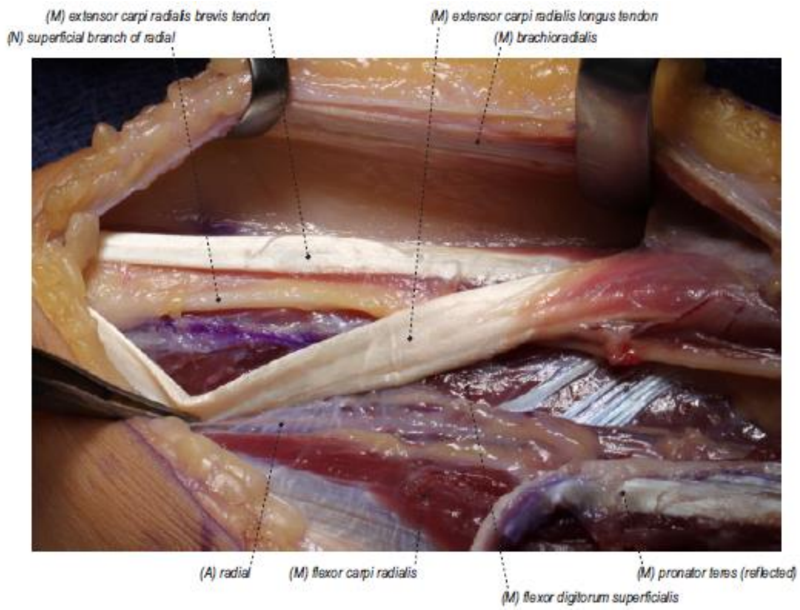

FIGURE 8: Identifying ECRB muscle for tendon transfer. The recipient ECRB for tendon transfer is located ulnar to the ECRL. By retracting the ECRL, one can observe the ECRB tendon.

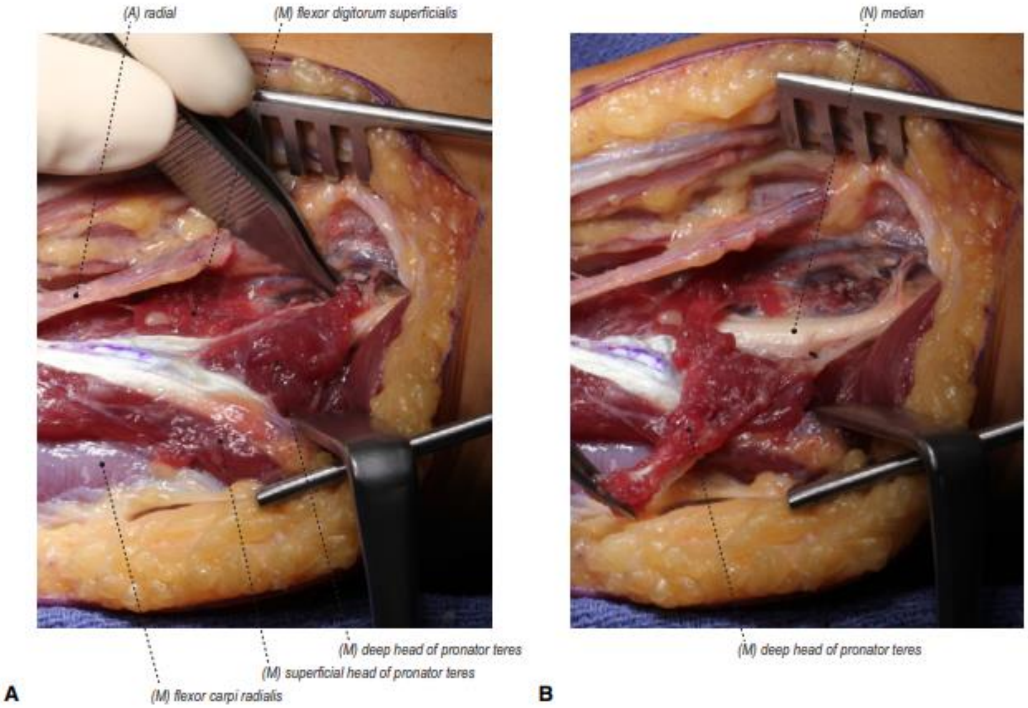

FIGURE 9: Release of the deep head of the PT muscle. **A** The deep head of PT is identified medial to the radial vessels and lateral to the superficial head. The deep head of PT is divided to expose the median nerve. **B** By releasing the deep head of PT, one can identify the median nerve. The FCR and FDS donor nerves for the median to radial nerve transfer are located on the medial aspect of the median nerve. The AIN can be used as a landmark to gauge where the donor nerves branch from the median nerve.

Wound closure and dressing

The wound is closed in layers, and both a pain pump and a drain are placed. The patient is immobilized with the elbow at 90°, forearm in pronation, wrist in neutral, and fingers free. The splint, drain, and pump are removed on the second or third postoperative day. A removable, custom splint or sling is then placed for an additional 10 days. If a PT to ECRB tendon transfer is performed, the wrist is positioned in extension, rather than neutral, and immobilization is continued for 4 weeks to protect the tendon repair. POSTOPERATIVE REHABILITATION Hand therapy is initiated at 10 to 14 days after surgery Patients are instructed to remove splints frequently for a home exercise program but to return them for functional use and during sleep. As with all radial nerve palsy patients, an effort is made to limit overstretching of the wrist and finger extensor muscles that may occur with unrestricted wrist and finger flexion. This is also important months later as the extensors exhibit early signs of reinnervation. The weak muscles will have a better chance of eliciting a good contraction when in the optimal length. When a PT to ECRB tendon transfer is performed with the nerve transfer, early intervention is more crucial and defaults to the tendon transfer protocol. In such cases, custom splinting is initiated at postoperative day 2–3 with the elbow immobilized at 90° flexion, the forearm pronated, and the wrist extended. At 2 weeks after surgery, immobilization of the elbow and forearm is discontinued, but the wrist remains splinted in extension until 4 weeks after surgery. Early motor re-education following nerve transfers begins within the first postoperative month with patient education. It is important for the patient to have a clear understanding of the anatomical changes that have been made. Time is taken to share images of the anatomy and to explain concepts in understandable terms so that the patient can better control these muscle groups with their altered innervation patterns. Phase 1 of motor re-education involves a focus on high-frequency, low-load activation of the donor muscle groups. The FDS and FCR donors are easy to activate in the first few weeks; the patient can do this simply by fisting actively on an hourly basis within their splint. At 2 weeks after surgery, the patient may remove their splint several times a day for active wrist flexion exercises (except when a PT to

ECRB tendon transfer is performed). At 1 month, light resistance putty is issued, with instruction in a series of 4 exercises: fisting, log rolling, resisted wrist flexion, and finger digs/pulls. Over time, more resistive putty is issued, which offers a passive component that assists the recipient muscle groups while donor groups are active.

Acknowledgment: This work was mainly following work done by Davidge et al. (13) for Median to Radial Nerve Transfers for Restoration of Wrist, Finger, and Thumb Extension

Conflict of Interest: None

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