Treatment of the Wrist and Hand in Cerebral Palsy

Michelle G. Carlson, MD, George S. Athwal, MD, Reuben A. Bueno, MD

From the Hospital for Special Surgery, Cornell University Medical College, New York, NY.

A comprehensive review of cerebral palsy is presented as it pertains to the examination and treatment for patients with wrist, hand, and finger deformities. Care is taken to provide several treatment options as they relate to specific deformities. (J Hand Surg 2006;31A:483–490.

Key words: Cerebral palsy, hand, wrist, tendon transfer.

Cerebral palsy (CP) is a musculoskeletal deformity caused by a static perinatal brain injury. The extent of motor function and sensibility involvement is variable. Motor involvement may take the form of spasticity, flaccidity, or athetosis (fluctuating between spasticity and flaccidity). The spastic involvement of a muscle often is accompanied with flaccidity of its antagonist, which often necessitates both releases and transfers to augment the antagonist.

The identification of upper-limb dysfunction usually is noted by 1 year of age. Infants normally develop refined pinch with opposition of the tip of the thumb to the index finger, whereas infants with CP do not reach this milestone. Infants with CP may develop a more primitive key pinch (thumb to side of index finger).

The typical position of the arm in CP is flexion of the elbow, pronation of the forearm, flexion of the wrist, and adduction of the thumb. The fingers can be flexed or hyperextended with a Swan-neck appearance. Evaluation of the patient with CP is a multistep process and involves input from the treating therapists. Videotaping the patient performing range-of-motion exercises on command and functional activities often is helpful. Extremity patterns of use may differ because spasticity kicks in as patients attempt to use their hand functionally. After reviewing videotapes and consulting with therapists a surgical plan should be formed. The goals of surgical intervention should be established and usually include a combination of functional improvement, hygiene, and aesthetics. Functional improvement is usually the primary goal; however, it may be unrealistic in patients with severely involved CP. Quality of life still is enhanced with improved hygiene and/or aesthetics of an extremity.

Many guidelines for surgical intervention have been described.[1–3] Voluntary hand use is probably the best predictor of functional improvement in the hand after surgery. Patients with athetoid CP should be approached with caution because surgery may worsen their condition by creating the opposite deformity after releases or transfers. Sensibility and intelligence quotient are less stringent guidelines because it is rare that a patient's intelligence quotient is so low that they cannot benefit from improved limb positioning for hygiene. Patients with decreased sensibility still benefit from improved hand position because the ability to see the thumb during activities improves function.

Options for surgical intervention are limited to 4 basic procedures. Musculotendinous units can be released or lengthened, tenodesed, or transferred/rerouted, and joints can be arthrodesed. A surgical plan is constructed by identifying the various joints and musculotendinous units involved and by selecting the appropriate procedures to address the deformities. It is important to consider the entire upper extremity when formulating a plan because procedures performed on one joint may affect the contiguous joint. For example, correction of a wrist flexion deformity may affect digital positioning: if there is pre-existing digital flexor tightness then correcting wrist flexion will lead to further digital flexor tightness unless they are addressed simultaneously.

Once the diagnosis of CP is made then patients should have an upper-extremity consultation to evaluate function and to check for contractures. Splinting may be necessary, however, it should be reserved mainly for nighttime use to avoid affecting daytime hand and arm function. Patients usually are seen annually and surgical intervention is considered ideal between ages 3 and 6. Trends for surgical intervention at a younger age exist for 2 reasons: there is some evidence that improved use of the extremity may improve cortical representation of the extremity and hopefully decrease the development of neglect; in addition surgical intervention may decrease the formation of contractures.

Wrist

Flexion deformity at the wrist is caused by weak wrist extensors and/or tight wrist flexors and eventually by capsular contracture. Surgical intervention is directed at correcting these imbalances. It is helpful to classify wrist flexion deformity into 3 groups: static, dynamic, and functional.

Static Deformity

Static wrist deformities have a fixed flexion contracture of more than 45°. This usually occurs in older patients and often necessitates wrist arthrodesis to correct the deformity. Occasionally tendon transfers or releases are possible and this decision often is made during surgery. If after release of the wrist flexor tendons there is a capsular contracture of the wrist then wrist arthrodesis is indicated. If the wrist can be extended to neutral during surgery then tendon transfers are possible. One wrist flexor may be lengthened and left in continuity while the other wrist flexor then may be transferred for wrist extension. Active control of both wrist flexors must be established before surgery.

Dynamic Deformity

Dynamic deformities of the wrist have no static contracture. Patients may have some active extension, but usually to 45° less than neutral. Effective treatment involves transfer of a wrist flexor to the radial wrist extensors.

Functional Deformity

Patients with functional deformities of the wrist may have full active range of motion, but on performing activities the wrist pulls into flexion as a result of spastic firing of the flexors. Treatment involves lengthening of the spastic flexors. No transfer for wrist extension is needed.

Wrist Examination

Physical examination of the spastic upper extremity may be difficult. Despite their best efforts patients often have difficulty cooperating with the examination. The examination includes measuring active and passive range of motion of the wrist and observing the patient performing activities of daily living because they may have good wrist control on command, however, during functional activities the wrist may assume a nonfunctional position. It is important to evaluate the function of the flexor carpi ulnaris (FCU), flexor carpi radialis (FCR), extensor carpi ulnaris (ECU), extensor carpi radialis brevis (ECRB), and extensor carpi longus when considering transfers about the wrist. The FCR and FCU can be palpated during active wrist flexion, and the radial wrist extensors can be palpated during active wrist extension. It is important to confirm the presence of a functioning FCR when considering harvesting the FCU for transfer. Firing of the ECU is easiest to palpate during active wrist ulnar deviation and extension. Active ulnar deviation should be assessed during flexion and extension. Ulnar deviation during flexion is caused by spasticity of the FCU and ulnar deviation during extension is caused by spasticity of the ECU.

Surgical Procedures

Wrist arthrodesis. Wrist arthrodesis is used for static wrist deformities. Through a longitudinal incision the extensor retinaculum is opened and the extensor pollicis longus (EPL) tendon is released from the third dorsal compartment. Subperiosteal dissection of the distal radius, carpus, and third metacarpal is performed. Release should be performed volarly of the FCU, FCR, and palmaris longus tendons through small transverse incisions at the wrist. A proximal row carpectomy usually is necessary to allow for placement of the wrist in a neutral position and also may help to decrease digital flexor tendon tightness. Wedge resection of the midcarpus also can be performed to allow correction of the deformity. The articular surfaces are decorticated with a burr and an AO straight wrist arthrodesis plate is applied. No additional bone graft is required other than that obtained from the proximal row carpectomy. The retinaculum then is re-approximated over the plate and the patient is placed in a volar plaster splint, which is changed to a short arm cast when swelling subsides. Casting is continued until fusion is confirmed radiographically, usually at 6 to 8 weeks.

Flexor carpi ulnaris to extensor carpi radialis brevis transfer. This transfer is performed for dynamic wrist deformities. The FCU is harvested through a small transverse incision at the volar wrist crease. It should be harvested as distally as possible and often right off of the pisiform. A transverse incision then is made at the musculotendinous junction of the FCU and a tendon stripper is used to release intervening adhesions. The FCU tendon then is delivered into the proximal wound. The FCU tendon then can be wrapped around the surface of the forearm to determine the level of the transfer to the ECRB. A transverse incision is made at this level and the tendon is tunneled under the subcutaneous tissues between the 2 incisions. A Pulvertaft weave then is performed between the FCU and ECRB with maximum tension on both tendons with the wrist in neutral position. The tendons are secured with a 3-0 nonabsorbable braided suture. When the forearm is elevated off the surgical field in the pronated position the wrist should assume a passive position of 20° of flexion. The wrist should not be in neutral or extension. Wounds are closed with absorbable sutures and the wrist is immobilized in 10° of extension for 4 weeks. After 4 weeks a removable wrist splint is applied and range of motion exercises are begun.

Extensor carpi ulnaris to extensor carpi radialis brevis transfer. This transfer is used for dynamic wrist deformities when the FCU is too spastic for transfer, the FCR is not strong enough to allow harvest of the FCU, or there is ulnar deviation deformity. It always should be combined with lengthening of the FCU. Extensor carpi ulnaris to ECRB transfer also can be used when the FCU is being used for transfer to the digital extensor tendons. Through a single transverse incision proximal to the extensor retinaculum the ECU can be harvested as far distally as possible and transferred to the ECRB in the same fashion as described for the FCU.

Flexor carpi ulnaris z-lengthening. The FCU z-lengthening procedure is performed for functional wrist deformities and in combination with the ECU to ECRB transfer. Through a small transverse incision over the FCU approximately 1 cm proximal to the wrist flexion crease the FCU tendon is identified. A z-lengthening of the tendon is performed and the ends are reattached end to end with 3-0 nonabsorbable braided sutures. The postoperative protocol is the same as for the FCU to ECRB transfer.

Fingers

There are 2 types of functional deformities of the fingers: (1) flexion deformities caused by tight digital flexors and/or weak digital extensors and (2) hyperextension deformities of the proximal interphalangeal (PIP) joints (Swan-neck deformity).

Finger Examination

Examination of the fingers should be performed with the wrist in neutral, flexion, and extension. If the patient cannot extend the wrist actively then the wrist can be held manually or splinted in neutral to evaluate finger function. Splinting occasionally may trigger a grasp reflex in the hand and then cannot be used for evaluation. With the wrist held in neutral, passive extension of the fingers and thumb should be performed. If the fingers and thumb cannot be extended fully then the digital flexors are tight and will need lengthening. Fractional lengthening of the digital flexors will be sufficient if the fingers can be extended fully with the wrist in the flexed position. If the fingers cannot be extended fully even with the wrist flexed then more lengthening is necessary and this is accomplished most easily with a superficialis to profundus transfer.

Assessment of active digital extension also is important. If the patient does not have active digital extension with the wrist in neutral then transfer to the extensor digitorum communis will be necessary. This is usually a transfer of the FCU to the extensor digitorum communis. It also is important to ensure that active extension of the digits is not restricted because of digital flexor tendon tightness.

Proximal interphalangeal joint hyperextension or Swan-neck deformity also should be evaluated with the wrist in a corrected neutral position. The amount of active hyperextension of the PIP joint should be measured. Treatment should be considered if joint hyperextension is more than 20°.

Surgical Procedures

Fractional lengthening of the flexor digitorum superficialis, flexor digitorum profundus, and flexor pollicis longus. Fractional lengthening of the flexor digitorum superficialis (FDS), flexor digitorum profundus (FDP), and FPL is indicated for digital flexor tendon tightness that occurs when the wrist is in the neutral position but that corrects when the wrist is flexed. A longitudinal incision is made over the musculotendinous junction in the midforearm. The separate FDS tendons are identified superficially and the conjoined FDP tendons are identified in the deep aspect of the wound. The ulnar nerve is protected ulnarly and the median nerve is protected between the FDS and the FDP. With retraction of the FDS and the FDP ulnarly the FPL can be identified within the incision radially. Fractional lengthening of the FDS and the FDP is performed with 2 transverse incisions in the tendinous portion of the musculotendinous junction. If necessary the FPL can be addressed in a similar fashion. During surgery it is important not to stretch the fractionally lengthened tendons to full extension, but to leave them in a position of function. No immobilization is used after surgery, and by actively extending the digits the patient stretches the lengthenings to the optimum tension.

Flexor digitorum superficialis to flexor digitorum profundus transfer. The FDS to FDP procedure is indicated when there is digital flexor tightness even with the wrist in maximal flexion. A longitudinal incision is made distal to the musculotendinous junction in the forearm. The superficialis tendons are identified superficially and the profundus tendons deep. The ulnar and median nerves are protected. With the hand held in the normal resting position the FDS tendons are sutured together as distally as possible and then transected distally. Similarly the FDP tendons are sutured together proximally and then transected proximally. The proximal FDS is reattached to the distal FDP in a side-to-side fashion, with the wrist in neutral and the fingers assuming the normal cascade position. After surgery the wrist is immobilized in flexion with the digits in an intrinsic plus position for 4 weeks. During this time passive range of motion of the fingers is performed. At 4 weeks the protective splint is discontinued and active range of motion is begun.

Flexor carpi ulnaris to extensor digitorum communis transfer. The FCU to extensor digitorum communis procedure is indicated for absent active extension of the metacarpophalangeal (MCP) joints. The FCU is harvested as previously described for the FCU to ECRB transfer. The digital extensor tendons then are identified through a dorsal incision and the FCU is woven through the extensor digitorum communis of the index, middle, ring, and small fingers in a pulvertaft fashion. Tension is set with the wrist in neutral and the fingers extended maximally. After surgery the wrist is immobilized in 30° of extension with the digits in full extension for 4 weeks. At 4 weeks a removable splint is made and active and passive range of motion exercises are begun.

Central slip tenotomy for Swan-neck deformity. The central slip tenotomy for a Swan-neck deformity procedure is indicated for active Swan-neck deformity in patients with active digital flexion from the corrected neutral position. A transverse incision is made dorsally, approximately 1 cm proximal to the PIP joint. The extensor mechanism is identified and a forceps is used to grasp the center of the tendon, making the separation between the central slip and lateral bands easier to identify. The central slip is transected transversely and the lateral bands are left intact. As the central slip is transected the demarcation between it and the lateral bands, if unclear before, becomes more apparent. The skin is reapproximated with absorbable sutures and the PIP joint is pinned in 10° of flexion for 4 weeks. At 4 weeks the pins are removed and active flexion is begun. Active extension is limited to lacking 10° from full extension with a figure-of-eight splint. At 8 weeks full range of motion is allowed.

Figure 1. Thumb adduction during grasp prevents this patient from being able to hold a bottle.

Thumb

The thumb is responsible for 40% of hand function and CP thumb-in-palm deformity markedly affects hand function. There are 2 important aspects of thumb-in-palm deformity: (1) the position of the thumb in the palm during fisting and (2) the inability to abduct the thumb when opening the hand. The inability to extend the thumb out of the palm with loss of the first web space is the true obstacle to use of the hand (Fig. 1). Even with an adequate web space thumb abduction is necessary to allow adequate visualization of the thumb in the pronated forearm. Visualization of thumb position provides the feedback necessary for optimum thumb function in the CP hand. Thumb abduction requires strong abducting muscles and relaxation of adductors. Also the skin of the first web space must be pliable enough to allow abduction. The primary muscle responsible for extension/abduction of the thumb is the extensor pollicis brevis (EPB). It extends/abducts the thumb carpometacarpal joint and the MCP joint. The EPL tendon is responsible for extension of the terminal phalanx in this abducted position but the EPL firing alone will produce adduction of the thumb ray.[7] For full thumb abduction both the EPL and EPB must function. The abductor pollicis longus, although named an abductor, has very little thumb abduction function and actually is more responsible for wrist radial deviation than thumb abduction.

The adducted posture of the thumb is caused by spasticity in the adductor pollicis and the first dorsal interosseous muscles. Release of these muscles usually is necessary to improve abduction of the thumb. In addition, the skin of the first web space contracts over time and usually requires release. The flexor pollicis longus (FPL) tendon also should be assessed for tightness.

Thumb Examination

There are 4 keys to evaluating adduction deformity of the thumb: (1) spasticity of the flexors and adductors, (2) flaccidity of the extensors and abductors, (3) hypermobility of the MCP joint, and (4) web-space skin contracture. The flexors and adductors are the FPL, flexor pollicis brevis, adductor pollicis, and first dorsal interosseous. The thumb metacarpal assumes an adducted position if there is spasticity of the adductor and first dorsal interosseous and the thumb MCP joint will flex with spasticity of the flexor pollicis brevis. Flexor pollicis longus spasticity is evaluated with the wrist in neutral and the thumb held radial to the index finger; if there is fixed flexion of the thumb interphalangeal joint then FPL lengthening will be required.

The extension and abduction of the thumb are performed by the EPB and EPL. The EPL may function well with the thumb in the adducted position, which may lead to interphalangeal joint hyperextension.

Thumb MCP joint hyperextension should be identified and addressed at the time of surgery because thumb abduction tendon transfers may produce unwanted MCP joint hyperextension. In addition, the first web-space skin may be contracted and require release at the time of surgical correction.

Surgical Procedures

The aim of surgical treatment is to address the 4 causes of deformity previously described. Spasticity of the thumb intrinsics is present in almost all thumb-in-palm deformities. The adductor pollicis and first dorsal interosseous muscles should be addressed primarily because the flexor pollicis brevis is involved less frequently. Release of the adductor may be performed at its origin[1,4–9] or its insertion.[2,4–7,10] The FPL also should be released if spastic.

Augmentation of thumb abduction has been described by a variety of tendon transfers including the brachioradialis,[11] palmaris longus,[6] FCR, FCU,[6,8] extensor carpi radialis longus and ECRB,[7] and FDS.[1,3] Rerouting of the EPL, FPL abductorplasty, and abductor pollicis longus, and EPB imbrication also have been described.[1,3,7,11–13] Rerouting of the EPL allows it to become a thumb abductor instead of an adductor and extensor. Of the earlier-described transfers, the senior author has found rerouting of the EPL tendon and a brachioradialis to EPB transfer the most effective. If the EPL is strong and good extension of the interphalangeal joint is possible with the wrist in neutral then EPL rerouting is performed as described later. If the EPL is not strong then a brachioradialis to EPB transfer is performed. It is important to examine the thumb MCP joint before transfer, otherwise abduction transfer may produce unwanted MCP joint hyperextension. A capsulodesis of the MCP joint can be performed at the time of adductor release if necessary.

Figure 2. The first web space is released through a double-opposing z-plasty incision. This allows for excellent visualization of the adductor and first dorsal interosseous and for releasing the contracture in the web space.

Adductor release. Release of the adductor is performed at its insertion in the first web space. Through a double-opposing z-plasty of the first web space (Fig. 2) the adductor tendon and muscle is released from its insertion on the first metacarpal, extensor hood, and sesamoid, and reattached proximally to the periosteum in the midshaft of the metacarpal with a 4-0 nonabsorbable braided suture (Fig. 3). A subperiosteal release of the first dorsal interosseous from the thumb metacarpal is performed proximally. Care is taken to avoid injury to the princeps pollicis artery as it ascends from the base of the web space along the ulnar border of the first metacarpal. After the first web-space release the FPL tendon should be assessed with the wrist in a neutral position. If full abduction and extension of the thumb is not possible then it too will need to be released, usually by fractional lengthening.

Metacarpophalangeal joint capsulodesis. If passive hyperextension of the thumb MCP joint exists

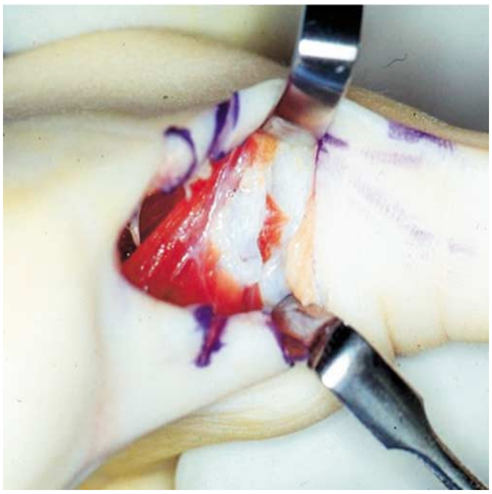

Figure 3. The adductor is taken down from its insertion on the thumb metacarpal and sesamoid.

then a capsulodesis may be performed through the web-space incision. The volar joint capsule is taken down from its insertion on the metacarpal along its ulnar side, leaving it attached to the ulnar sesamoid. It then is advanced proximally and sutured more dorsally to the periosteum of the first metacarpal. Performing this only on the ulnar side of the MCP joint will be secure enough to prevent MCP hyperextension after tendon transfer. The MCP joint then should be held in 10° of flexion for 4 weeks with a K-wire.

Abduction augmentation. Augmentation of thumb abduction is accomplished primarily by 1 of 2 procedures. If the EPL can extend the thumb interphalangeal joint fully with the wrist in neutral (either held actively or passively), then it is rerouted to become an abductor. If the EPL is nonfunctional with the wrist in neutral then the brachioradialis is transferred to the EPB or to the rerouted EPL.

Extensor pollicis longus rerouting. Through a transverse incision over the third dorsal compartment, proximal to Lister's tubercle, the retinaculum of the third dorsal compartment is incised. The EPL is removed from its tunnel and allowed to migrate radially (Fig. 4). Through a second transverse incision just distal to the first dorsal compartment a distally based slip of the abductor pollicis longus is harvested. A radial pulley is created with the abductor slip as it is wrapped around the EPL tendon, pulling and tethering it radially. The abductor slip is sutured to the most volar aspect of the retinaculum of the first dorsal compartment (Fig. 5). The adequacy of the radial pulley is checked during surgery by traction on the EPL at the wrist producing thumb abduction instead of extension and adduction (Fig. 6). If hyperextension of the MCP joint is noted before surgery a capsulodesis is performed concurrently. The first web space is held in abduction with a percutaneous 1.4-mm (0.045-in) K-wire, and a nonremovable thumb spica splint is applied. Four weeks after surgery the K-wire is removed and the thumb is placed in a removable thumb spica splint and therapy is begun.

Three months of postoperative therapy is recommended. The initial postoperative therapy goal is to have the patient actively attempt to inhibit any thumb adduction during proximal exercises. This is assessed and achieved before active EPL/abductor pollicis brevis firing is attempted, usually within 2 weeks after splint removal. Therapy then progresses to include light cylindric grasp and opposed light pinch of small objects, with the focus on balanced palmar and radial abduction. Squeezing and tight pinch are avoided for the first 3 weeks of therapy to avoid encouraging the preferred thumb adduction pattern. If the patient is unable to inhibit adduction at least partially then squeezing and tight grasp are limited in the therapy program but are included as needed for activities of daily living. At 3 weeks after cast removal all light activities of daily living are encouraged including those with pinch and grasp. Activities of daily living then progress as tolerated with the splint discontinued at 4 weeks after cast removal.

Brachioradialis to extensor pollicis brevis transfer. A 2-cm transverse incision is made 3 cm proximal to the tip of the radial styloid. The subcutaneous tissues are spread bluntly, with care taken to avoid injury to the superficial branches of the radial nerve. The brachioradialis tendon is identified and taken down from its insertion on the radius as distal as possible. The EPB tendon is identified in the distal aspect of the wound. It tends to be a small tendon and if it is too small then the rerouted EPL may be used

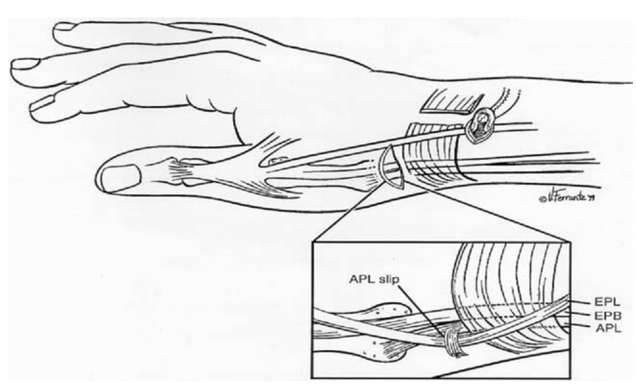

Figure 4. The third dorsal compartment is opened over the EPL tendon to allow it to migrate radially.

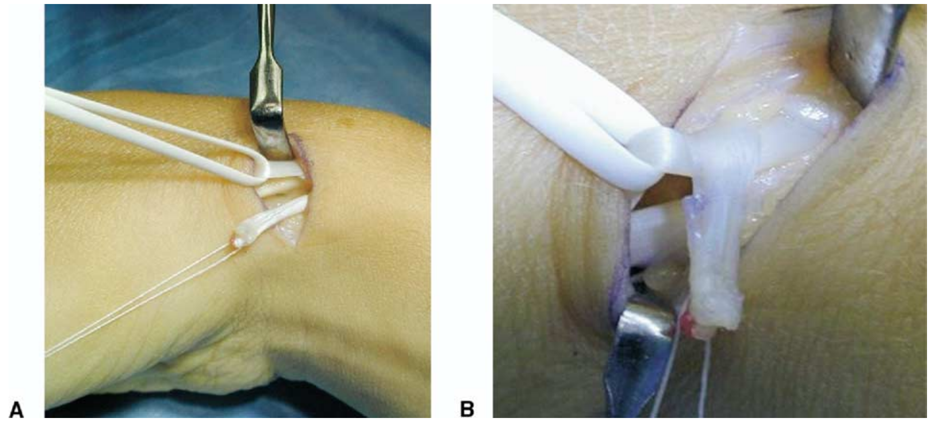

Figure 5. The most volar slip of the abductor pollicis longus tendon is transected distally to create a radial pulley for the EPL tendon (marked with vessel loop).

as described earlier. The EPB is transected as proximal as possible. The EPB then is woven into the brachioradialis tendon in a pulvertaft fashion and secured with nonabsorbable sutures (Fig. 7). Maximum tension is placed on the 2 tendons, with the wrist in neutral during the weave. The tension can be assessed after the transfer because wrist extension should adduct the thumbs and wrist flexion should abduct the thumb. The postoperative regimen is the same as for EPL rerouting.

Thumb-in-palm disorder usually requires release of the pathologic adduction to improve thumb abduction. Release of the thumb adductor and the first dorsal interosseous along with EPL rerouting or a brachioradialis to EPB transfer reliably improves hand grasp (Fig. 8).

Cerebral palsy involvement of the wrist, fingers, and thumb is common. A multidisciplinary approach involving the pediatrician, occupational therapist, physical therapist, and surgeon allows the formulation of a patient-specific global treatment plan. Serial examination of objective parameters (range of motion) and functional abilities

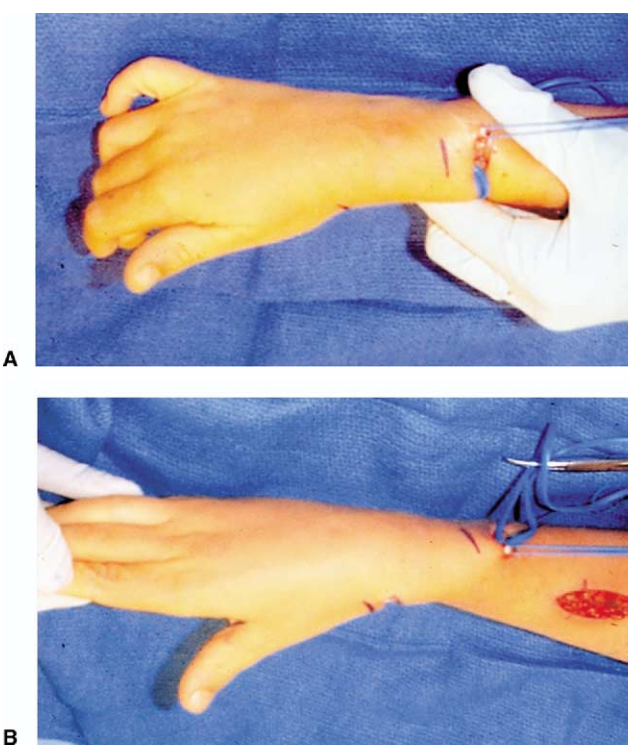

Figure 6. (A) Traction on the EPL in its anatomic position produces extension and adduction of the thumb. (B) After rerouting of the EPL, traction produces abduction of the thumb.

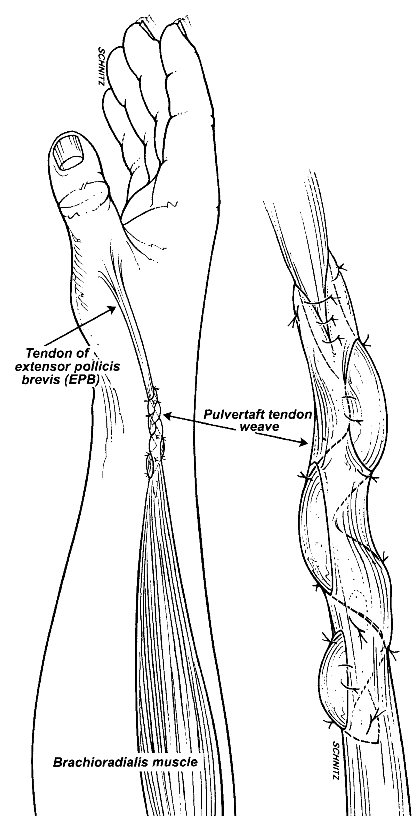

Figure 7. The brachioradialis tendon is transected distally and the EPB is transected proximally and woven in a pulvertaft fashion into the brachioradialis.

Figure 8. Release of the adductor and first dorsal interosseous and rerouting of the EPL. Attempted abduction of the thumb before surgery produces adduction of the first metacarpal. After surgery a 60° web space is maintained actively.

assists the surgeon in determining the patient's needs and limitations.

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Corresponding author: Michelle G. Carlson, MD, Hospital for Special Surgery, Cornell University Medical College, 523 East 72nd St, New York, NY 10021; e-mail: carlsonm@hss.edu.

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