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An Insight about Tendon transfer for median nerve palsy

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Abstract: The surgeon may be presented with a child who has sustained a substantial loss of median nerve substance. Defects larger than 4–6 cm restored by nerve grafts are associated with poorer reinnervation outcomes than smaller defects. Another difficult situation involves median nerve lacerations well proximal to the elbow where the distance from repair to the first points of innervation may be longer than what the muscles have for time to reinnervate (usually associated with other serious injury involving the ulnar nerve, the brachial artery, and even the musculocutaneous nerve). In the latter situation, the healing nerve repair may simply take too long to ever innervate critical musculature before irreversible end-plate demise. One option is to resort to tendon transfer reconstruction early, and the techniques are detailed below. The other option is to restore critical portions of the median nerve using nearby healthy nerve tissue. Previously described donor motor nerves include the motor nerve to the brachialis muscle and the posterior interosseous nerve (both the supinator and extensor carpi radialis brevis branches). Donor sensory nerves include the lateral antebrachial cutaneous nerve, the superficial radial sensory nerve, and the common digital nerve to the small/ring finger (ulnar nerve). Examine the thumb carefully by noting its resting position, state of all the muscles moving the thumb and its three joints: the carpometacarpal (CMC) joint at the base, the metacarpophalangeal (MCP) joint in the middle and the IP joint at the distal part. Check the CMC joint for subluxation or contracture in the extended and externally rotated position. Check the MCP joint for arthritis and instability in flexion. Check the IP joint for contracture. Further, verify that the thumb web is adequate and not contracted. When you suspect any joint problem like subluxation or arthritis, radiographs must be taken to confirm the suspicion. When joint problems are present, or, when there is contracture of the thumb web or the IP joint flexion contracture of more than 20°, then transfer cannot be done before correcting them

Keywords: *median nerve palsy*

Introduction

The median nerve receives fibers from roots C6, C7, C8, T1 and sometimes C5 [1]. It is formed in the axilla by a branch from the medial and lateral chords of the brachial plexus, which are on either side of the axillary artery and fuse together to create the nerve anterior to the artery. The median nerve is closely related to the brachial

artery within the arm. The nerve enters the cubital fossa medial to the brachialis tendon and passes between the two heads of the pronator teres. It then gives off the anterior interosseus branch in the pronator teres [1].
The nerve continues down the forearm between the flexor digitorum profundus and the flexor digitorum superficialis. The median nerve emerges to lie between the flexor digitorum superficialis and the flexor carpi ulnaris muscles which are just above the wrist. At this position, the nerve gives off the palmar cutaneous branch that supplies the skin of the central portion of the palm [2].
The nerve continues through the carpal tunnel into the hand, lying in the carpal tunnel anterior and lateral to the tendons of the flexor digitorum superficialis. Once in the hand, the nerve splits into a muscular branch and palmar digital branches. The muscular branch supplies the thenar eminence while the palmar digital branch supplies sensation to the palmar aspect of the lateral 3+1/2 digits and the lateral two lumbricals [2].

Etiology

Compression, stretch, or traumatic disruption of the nerve may result in median nerve palsies. As noted, the key to providing appropriate care to patients with median nerve palsy is accurately identifying the source of nerve dysfunction through a careful physical examination and when needed, confirming injury with advanced diagnostic techniques. Penetrating injuries to the upper arm can result in a median nerve palsy. Injuries to the median nerve at this location often result in a vascular injury given the nerve's proximity to the brachial artery. Such an injury to the brachial artery will most often result in an under perfused extremity, constituting a vascular emergency. There have also been case reports of damage to the median nerve in the upper extremity after a brachial angiography [3].
Compression of the median nerve can occur at multiple sites in and around the elbow. Median nerve impingement may occur at the ligament of Struthers and supracondylar process of the medial epicondyle, or slightly more distal at the bicipital aponeurosis as well as between the heads of pronator teres [4].
Penetrating injuries between the elbow and wrist may result in laceration or injury to the median nerve or the anterior interosseous nerve (AIN) and the palmar cutaneous branches of the median nerve [5].
Most commonly, palsies of the median nerve are caused by compression at the carpal tunnel. Known as carpal tunnel syndrome, symptoms are often alleviated by conservative measures but have a high treatment success rate when surgical intervention is required [6].

History and Physical Examination

When median nerve palsy is suspected, a history should investigate the timing of onset and duration of symptoms. Practitioners should identify any temporal factors, such as pain that is worse at night or with activity, and any other aggravating or relieving factors affecting a patient's symptoms [7].
Patients with diabetes and thyroid disease are at increased risk for carpal tunnel syndrome, and therefore a thorough medical history can help practitioners better diagnose higher-risk patients [8].
Physical exam should focus on identifying all motor and sensory deficits and using these findings to identify the locus of a patient's pathology. As discussed, median nerve injury most commonly presents from compression at the carpal tunnel, but compression also may occur at the level of the elbow as with pronator syndrome. Indeed, a careful practitioner should also consider nerve compression injury more proximally in either the brachial plexus or cervical spine, where disc or foraminal pathology can create symptoms in the median nerve distribution. Physicians should not overlook any vascular injury, especially in the setting of a high median nerve injury in the upper arm. Urgent intervention may be required in acute cases, such as an expanding hematoma, or when worsening motor deficits are identified to prevent permanent progression of nerve palsy [9].
Compression of the median nerve is most common at the level of the carpal tunnel, where the nerve enters the hand under the transverse carpal ligament. The median nerve provides sensation to the index, middle, and ring fingers via the digital nerves. It is important to note that sensation to the radial palm is provided by the palmar cutaneous branch, which branches proximal to the transverse carpal ligament in the forearm and therefore is not a component of carpal tunnel syndrome. With carpal tunnel syndrome, practitioners may observe

weakness in the thenar eminence. Isolation of the opponens pollicis by asking the patient to palmarly abduct the thumb helps to identify weakness in the median nerve. It is worth noting that the flexor pollicis longus and the flexor digitorum profundus to the index and middle fingers should be intact as they are innervated by the anterior interosseous nerve which branches from the median nerve just distal to the elbow [10].

Phalen's test is used to assess for compression at the carpal tunnel. It is considered positive when there is a reproduction of symptoms after full flexion of the wrist for 60 seconds [11].

Tinel's sign may also be used to assess for compression at the carpal tunnel. It is considered positive when a repeated tapping over the carpal tunnel reproduces symptoms in the hand consistent with median nerve pathology [2].

The next most likely site of a median nerve compression injury would be at the level of the cubital fossa in pronator syndrome. Pronator syndrome is frequently misdiagnosed as carpal tunnel syndrome. This common error leads to significant morbidity caused by a delay of appropriate care. Compression of the median nerve in the cubital fossa would have significant similarities to the presentation of carpal tunnel symptoms, but an understanding of the anatomy will reveal subtle differences in the examination. Most obviously, pronator syndrome results in compression proximal to the palmar cutaneous branch of the median nerve and thus may result in numbness over the radial palm, distinguishing itself from carpal tunnel syndrome. Similarly, compression proximally at the ligament of Struthers occurs before the divergence of the anterior interosseous nerve. Theoretically, patients could present with weakness in the deep flexors such as flexor digitorum profundus (FDP) to the index and middle fingers, as well as to the flexor pollicis longus (FPL) which are both innervated by the anterior interosseous nerve. Placing the elbow in full extension and pronating the arm may reproduce symptoms of pronator syndrome, and may help practitioners distinguish between pronator syndrome and carpal tunnel syndrome [12].

Diagnosticians must always evaluate the neck in patients with presumed median nerve injury or carpal tunnel syndrome. Double crush syndrome is defined as an injury to a nerve at both a distal site of compression as well as proximally such as in the case of a coexistent cervical disk herniation or foraminal stenosis. This condition is most commonly identified when patients have an unsatisfactory resolution of symptoms after a carpal tunnel release [13].

Osterman et al. found in a prospective study that patients who suffered from double crush syndrome reported more "paresthesias" rather than "numbness" compared to patients who had isolated carpal tunnel syndrome. He also found that grip strength was decreased more with double crush syndrome compared to carpal tunnel syndrome [14].

Of note, radiography of the cervical spine is not currently recommended for evaluation of double crush syndrome by current literature, particularly in the older patient population as there is a very high incidence of asymptomatic degenerative changes of the spine. MRI may be useful but is cost-prohibitive and not necessary in most cases. Therefore, history and physical examination with documentation of such examination techniques as Spurling's cervical spine maneuver to identify cervical nerve root compression, are important tools to identify double crush syndromes [15].

Diagnosis

Diagnosing median nerve injury can be made on purely clinical grounds, and in the face of an open wound with symptoms consistent with a median nerve deficit, the diagnosis is usually confirmed by surgical exploration. Diagnosing the site and extent of injury in patients who present late after injury may be difficult. Likewise, in those with closed median nerve injury and in some cases of iatrogenic injury, diagnosing the level of injury may be difficult [16].

A comprehensive overview of the use of electrodiagnostic tests in the evaluation of nerve injuries is beyond the scope of this review, but several points bear emphasis. Electrodiagnostic tests can be helpful in nerve injuries and may aid in diagnosing the level of the lesion as well as whether the nerve is partially intact. These tests may also diagnose anomalous nerve communications when they are present. Patients with incomplete nerve laceration may have some loss offunction (either motor or sensory) with an otherwise normal examination for the normal function of that nerve. In incomplete nerve injuries (neurapraxia), the compound muscle action potential (CMAP) and nerve action potential (NAP) distal to the site of injury are maintained. Proximal stimulation of the nerve likewise shows partial or complete conduction block in the face of the maintenance of CMAP and NAP. As the nerve recovers, the conduction block will resolve, albeit with some ongoing slowing of conduction, which should not interfere with function. In complete nerve injuries (axonotmesis), CMAP and NAP distal to the injury show a decrease in amplitude roughly proportional to the degree of axonal loss. Loss of amplitude is complete for both by about 11 days postinjury and will not improve without nerve repair [17].

Although traditional teaching is that early electrical studies (earlier than 3 weeks after injury) are not helpful, there may be some benefit to performing these in the first few weeks. In extensive soft tissue injuries in which the level of nerve injury may not be clear, early electrodiagnostic studies can isolate the exact level of injury because the distal axons will conduct for about a week but there will be no conduction across the site of injury. Also, the presence of motor unit action potentials suggests that the nerve lesion is incomplete. Usually most information will be obtained if electrical studies are performed 3 weeks after median nerve injury [17].

The technique of nerve imaging remains in its relative infancy, but increasing interest by radiologists and improvements in the technique of magnetic resonance neurography (MRN) have brought about some promising advances. With moderate stretch injury, MRN will show nerve enlargement and expansion of the fluid space within the nerve along the zone of injury. With high-grade nerve injury (axonotmesis), a neuroma-in-continuity may be visible, or nerve disruption and neuroma formation may be seen in the proximal nerve stump. These changes are best seen in both T1 and T2 imaging techniques, which can complement each other [18].

Operative Treatment of Median Nerve Injuries

The surgical approach to any peripheral nerve injury is best understood by dividing the injury into the treatment of acute versus chronic injuries and sharp lacerations versus stretch/crush injuries where the “zone” of nerve injury is greater. The majority of surgical treatment in acute and subacute injuries involves lacerated median nerves as the presence of an open wound in the face of a nerve deficit often infers a nerve laceration. In contrast, the majority of surgery in the chronic setting manages stretch and crush injuries, as these are the mechanisms of injury associated with most closed injuries. The challenge in both situations is accurately assessing the zone of injury so that the surgeon can confidently repair or graft healthy viable nerve endings resulting in a greater likelihood of success. The challenge more often found in the latter situation is assessing the nerve injury intraoperatively, especially when the nerve is in continuity and there is a neuroma in continuity [19].

Another issue critical to the surgical treatment of the median nerve issue concerns the estimated time of nerve regeneration. Repaired and healing nerves advance at a rate of about 1 mm/day. The target muscles for reinnervation start the process of internal degeneration the moment of denervation, and it is assumed and understood that at some point in time, 18–21 months from the time of injury, the denervated muscles undergoes irreversible end-plate demise while the muscle fibers themselves undergo morphological changes that will make them irreversibly fibrotic. Moreover, the sooner the muscles are reinnervated, the greater the potential return of strength. The surgeon must take these factors into account as he/she decides the optimum time to intervene along with the best methods of repair and reconstruction [20].

Sharp knife lacerations and penetrating injuries secondary to glass are a common cause of median nerve injury in children and typically present soon after the injury [5].

If a nerve deficit is identified or suspected, surgical exploration is warranted. The laceration may be explored acutely if other injuries require urgent surgical intervention (acute hemorrhage) or can be delayed for up to a week or so. One of the advantages of delayed exploration is the better ability to gauge the zone of injury that can extend beyond the immediate margins of the lacerated nerve ends. The dissection and identification of the injured structures is generally easier if performed earlier, before scar tissue has the opportunity to form, and the nerve ends retract proximally and distally from the site of the laceration. In the setting of an open fracture with an associated median nerve deficit, operative exploration at the time of fracture debridement and fixation is advised [21].

Primary repair of the median nerve is usually possible in the acute and subacute setting without the need for substantial mobilization, posturing of the elbow or wrist, or nerve graft/conduit provided a narrow zone of injury [22].

Even if the zone of injury is up to 2 cm, or viable nerve ends are about 2 cm apart, a primary repair is achievable. If the gap is greater than 4cm; however, a 'bridge' will be necessary [23].

The lacerated nerve ends are prepared by sharp resection until the organized internal architecture of the nerve is visualized and appears healthy [24].

Less resection is generally required in both lacerations and acute repairs, while crush, stretch, and contaminated injuries can lead to considerable nerve damage proximal and distal to the visible zone of injury even in the acute setting. A tension-free repair is critical to the potential for nerve recovery. During repair of an acute or chronic nerve injury, elongation of 15 % results is a severe decrease in blood flow and therefore a decreased potential for nerve regeneration [25].

Positioning and exposure of the median nerve can help facilitate a tension-free repair. With the patient in the supine position and the operative arm placed on a stable hand table, flexion of the wrist and hand can help approximate the ends of the nerve and decrease tension across the repair site. This position can be maintained intraoperatively with the use of any commercially available surgical hand positioner/immobilizer. Careful mobilization of potential soft tissue tethers proximal and distal to the repair can also aid in decreasing tension. Proximal forearm injuries to the median nerve may require division of the pronator fascia to increase visualization and ability to mobilize the proximal portion of the nerve [26].

The clinician should consider release of any known areas of constriction distal to repair site as compression has been reported to delay and impair nerve regeneration. In distal forearm median nerve injuries, release of the carpal tunnel should be considered. When injuries to the median nerve occur at the level of the wrist or palm, the transverse carpal ligament will likely need to be released for proper exposure of the proposed site of repair [27].

Primary surgical repair can be epineural, fascicular, or group fascicular. For digital nerve lacerations, an end-to-end epineural repair is performed with 9-0 nylon using the microscope. An epineural repair with 8-0 nylon can also be performed for more proximal lacerations to the median nerve in the forearm and wrist. The advantages of the epineural repair lie in its surgical simplicity and gentleness compared to other repairs that require internal dissection and damage to the perineural vessels. The surgeon can use the epineural vascular anatomy to line up vessels as well as aligning matched fascicles to perform as anatomic a repair as possible [24].

A fascicular repair requires stripping the outer epineurium and then directly aligning the perineurium of individual fascicles within the median nerve. This is more feasible distally in the forearm and wrist level as the internal fascicles are organized into a more predictable alignment and there are fewer in number [28].

A compromise between the two techniques is that of grouped fascicular repair, which requires less traumatic dissection but aligns groups of fascicles with segmental sutures through the inner epineurium. This technique is particularly useful in the distal median nerve in the forearm where the intraneural topography is well documented [29].

Despite multiple investigations, the superiority of epineural or fascicular repairs has not been definitively proven [30].

Cabaud et al. demonstrated no statistically significant difference in the results of peripheral nerve repairs performed with epineural or perineural fascicular techniques [31].

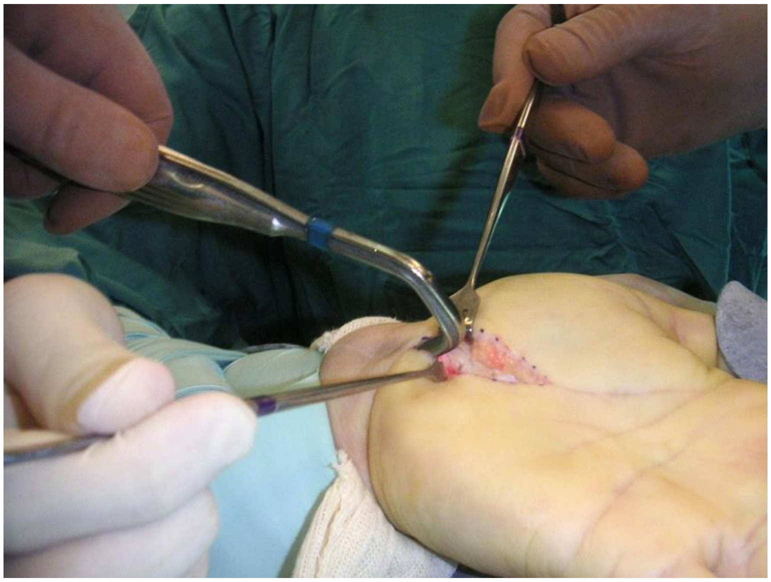


Figure (1):Lighted retractor allows direct visualization of transverse carpal ligament, which can be divided under direct vision with knife or scissors. [25]

Figure (2):Cannula is inserted inside carpal space, with groove of instrument facing up. [25]

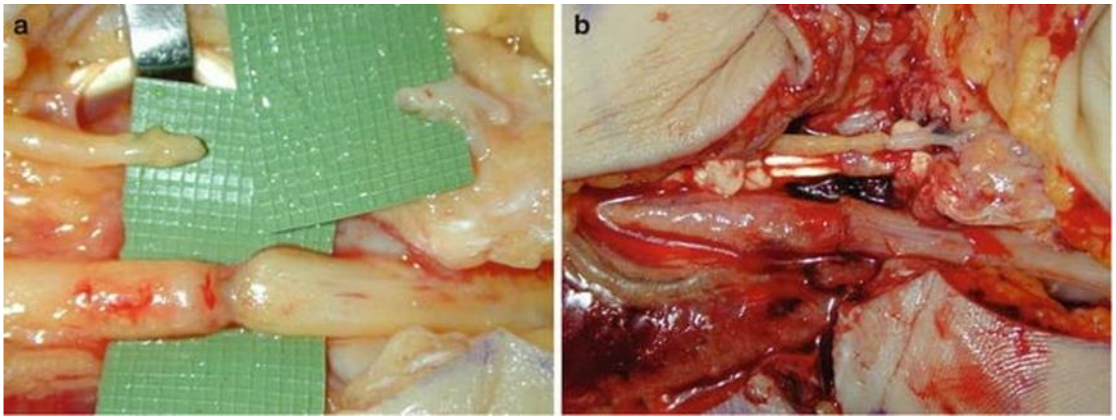


Figure (3): (a) Median nerve laceration in forearm. (b) Primary epineural repair of median nerve in forearm [32].

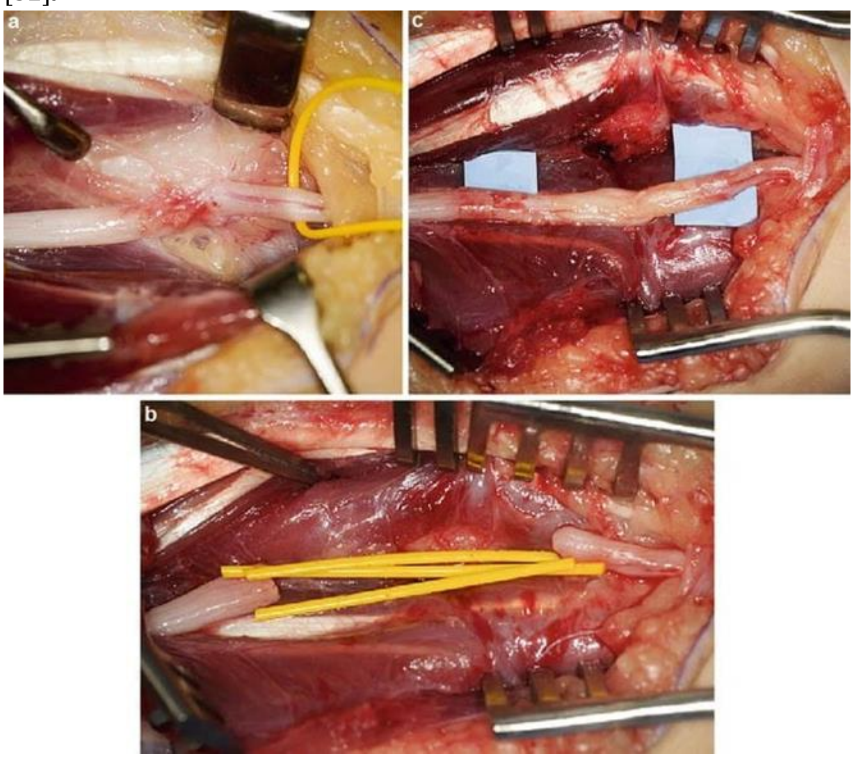


Figure (4): (a) Photograph of a median nerve exploration in the forearm for a child who failed to recover median nerve function following a palsy sustained as the result of a displaced both bones forearm fracture. Intra-operative nerve testing failed to demonstrate any evidence of conductivity across the zone of injury. (b) Proximal and distal stumps of healthy nerve left once the zone of injury was sharply resected. This defect is too large for primary repair. (c) Median nerve is reconstructed using auto-cable grafts secured at each stump with fibrin glue and reinforced with nerve-tubes [33].

Although microsurgical repair of peripheral nerves is generally performed using nonabsorbable microsutures, the development of fibrin adhesives offers a sutureless alternative. Theoretically, nerve repair utilizing adhesive alone could decrease operative time and traumatic handling of the nerve ends [34].

Moy et al. reported an improvement in the speed of repair of peripheral nerves using a fibrin seal versus suture, but found increased reactive changes within the earlier periods of nerve regeneration histologically [35].

However, others have demonstrated decreased inflammatory response and an environment more conducive to nerve growth when using fibrin adhesives to perform a peripheral nerve repair [36].

Overall, children are believed to have better potential for functional motor and sensory recovery following nerve injury and nerve repair. Primary repair of a median nerve laceration in an end-to-end fashion is preferred over use of a graft or conduit [37].
Hudson et al. found very satisfactory return of opponens pollicis function (4.5 out of 5) and a mean static two-point discrimination of 5 mm in children who underwent primary epineural repair of the median nerve [38].
In children who sustained penetrating injuries to the median nerve from glass, repair of the median nerve resulted in very satisfactory sensory return and acceptable motor function, with the best results seen in the children who underwent primary fascicular repair [39].
In studies that compare the results of repair and grafting among the various upper extremity nerves, median nerve injuries tend to respond very favorably to surgical repair and reconstruction compared to the radial and ulnar nerves [40].
For segmental defects in the median nerve of 3–4 cm or greater, a tension-free end-to-end repair is difficult to achieve primarily. Options for bridging the defect when positioning the wrist/elbow and mobilizing the nerve proximally and distally are insufficient include autograft, allograft, and nerve conduit. Autografts remain the most thoroughly researched and proven of the three options for repairing longer nerve gaps. Autografts are obtained from sensory nerves of similar size to the segment of the median nerve in need of grafting. The sural nerve can be used (and cabled) for sections of the median nerve in the forearm. The medial and lateral antebrachial cutaneous nerves, the medial brachial cutaneous nerve, or the posterior interosseous nerve from the dorsum of the wrist can be employed for more distal areas of injury to the median nerve in the palm and digits. Results of median nerve grafting with autograft in children are generally superior to that found in adults, but are inferior to results of primary nerve suture [41].
Ceynowa et al. performed a retrospective review of children and adolescents who underwent nerve grafting to the median or ulnar nerves using sural nerve grafts with a mean graft length of 2.8 cm. Although results were good overall with a mean DASH score of 14.6 (average period of observation of 7 years), two-point discrimination return was incomplete. Motor function was better in patients with median nerve injuries. The results of nerve grafting to restore function in the setting of long segmental defects (>5 cm) are somewhat mixed [42].
Long segmental defects can be grafted with favorable results, but shorter defects seem to experience better outcomes [43].
Allograft presents an alternative to autograft, without the morbidity or the residual sensory deficit left by the harvest of an in vivo graft. Previous use of allograft has been hindered by considerable immunogenicity requiring the use of immunosuppressive mediations. Processed nerve allografts, consisting of decellularized predegenerated human nerve tissue, are now available and do not require suppression of the patient's immune response. Karabekmez et al. reported return of adequate sensation in hand and finger segmental nerve defects of 0.5–3 cm using decellularized nerve allograft [44].
Recent data has shown promising outcomes in reconstruction of peripheral nerve gaps from 5 to 50 mm using allograft nerve [45].
Whitlock et al. demonstrated superior outcomes in an animal model with peripheral nerves coapted utilizing decellularized allograft to use of a type 1 collagen conduit. However, in their study, autograft results were superior to that of the allograft [46].
Synthetic bioabsorbable nerve conduits are readily available and composed of collagen, polyglycolic acid, (PGA) or caprolactone. Although often used for digital sensory defects, synthetic conduits have also been utilized in larger mixed motor and sensory nerves, such as the median nerve. It is generally accepted that conduits should not be used to bridge nerve deficits of larger than 3 cm. Many studies report encouraging results of nerve regeneration using conduits; however, the gaps are often shorter than 3 cm. Dienstknecht et al. demonstrated that type 1 collagen conduits successfully reconstructed median nerve segmental defects in the forearm of 1–2 cm [47].

The ideal nerve conduit would be nonimmunogenic and resorb at the same rate as the regeneration of the axons of the nerve being repaired. Both type I collagen conduits and PGA conduits are permeable, allowing diffusion to aid in the regeneration of the entubulated nerve. Collagen generally resorbs within 9 months of implantation, and PGA resorbs in approximately 6 months [48].

There are no randomized controlled trials comparing the 3 FDA-approved bioabsorbable conduits; however, individual studies of each material (collagen, PGA, caprolactone) have each demonstrated good to excellent results in restoration of sensation [49].

Peripheral nerves move with respect to their surrounding soft tissues in vivo and stretch and shorten to some degree. Preventing scar formation and adhesions helps to reduce the risk of creating a new site of tension and/or compression and helps in the overall rehabilitation of the child. The surgeon must note how range of motion of the proximal and distal joints affects tension on the median nerve repair and then use this intraoperative assessment to guide postoperative care. Allowing the fingers and thumb to move immediately helps create differential gliding between the extrinsic finger flexors and the nerve, and allowing the wrist and forearm and elbow to move early in the postoperative period helps create differential gliding between the two heads of the pronator and around the biceps tendon. It is appropriate to engage the help of a qualified physiotherapist to help ensure compliance through splinting and by monitoring and guiding motion. Surgical findings may mandate restricting motion to within specific arcs of motion to minimize tensioning the nerve repair. Communication and guidance with physiotherapy helps create the environment to maximize the child's outcome. Sensory reeducation has also been shown to improve outcomes, but to a limited extent [50].

Median Nerve Transfers

The surgeon may be presented with a child who has sustained a substantial loss of median nerve substance. Defects larger than 4–6 cm restored by nerve grafts are associated with poorer reinnervation outcomes than smaller defects. Another difficult situation involves median nerve lacerations well proximal to the elbow where the distance from repair to the first points of innervation may be longer than what the muscles have for time to reinnervate (usually associated with other serious injury involving the ulnar nerve, the brachial artery, and even the musculocutaneous nerve). In the latter situation, the healing nerve repair may simply take too long to ever innervate critical musculature before irreversible end-plate demise. One option is to resort to tendon transfer reconstruction early, and the techniques are detailed below. The other option is to restore critical portions of the median nerve using nearby healthy nerve tissue. Previously described donor motor nerves include the motor nerve to the brachialis muscle and the posterior interosseous nerve (both the supinator and extensor carpi radialis brevis branches). Donor sensory nerves include the lateral antebrachial cutaneous nerve, the superficial radial sensory nerve, and the common digital nerve to the small/ring finger (ulnar nerve) [51].

Chapter (3)

Tendon transfer for median nerve palsy

EVALUATION OF THUMB

Examine the thumb carefully by noting its resting position, state of all the muscles moving the thumb and its three joints: the carpometacarpal (CMC) joint at the base, the metacarpophalangeal (MCP) joint in the middle and the IP joint at the distal part. Check the CMC joint for subluxation or contracture in the extended and externally rotated position. Check the MCP joint for arthritis and instability in flexion. Check the IP joint for contracture. Further, verify that the thumb web is adequate and not contracted. When you suspect any joint problem like subluxation or arthritis, radiographs must be taken to confirm the suspicion. When joint problems are present, or, when there is contracture of the thumb web or the IP joint flexion contracture of more than 20°, then transfer cannot be done before correcting them [52].

Checking the CMC joint [53]

Hold the metacarpal of the thumb with your hand and push and pull the thumb along its long axis. When the joint is normal, it does not move up and down during the manoeuvre, but when the joint is subluxated it does.

Take hold of the thumb by its metacarpal, lift it off and across the palm as much as possible. If the terminal phalanx of the thumb can now face the base of the little or the ring finger, it indicates that there is no contracture of this joint in external rotation.

Checking the MCP joint [54]

If there is swelling of this joint, or, if on passively moving the joint you feel crepitus or elicit abnormal or excessive movement in any direction, it suggests arthritis of the joint. Radiographic examination is indicated.

Ask the patient to hold the thumb stiff whilst you push it back at the terminal phalanx. When there is instability, this joint buckles into a hyperextended position (the so-called “Z” deformity) during this manoeuvre. In many hands, the Z deformity (MCP joint extension) is present to a varying extent even whilst the thumb is at rest {indicating instability of the MCP joint in flexion} and becomes even more pronounced when you do this test.

Checking the IP joint

For contracture

Take hold of the proximal phalanx of the thumb with one hand and the distal phalanx with the other hand and passively extend the distal phalanx as much as possible. The extent of extension at this joint varies in different ethnic groups, it being quite high amongst Asians. When the joint cannot be fully extended, measure the extent of flexion contracture with a goniometer and record the contracture angle. If there is flexion contracture of more than 30° refer the patient to a specialist center [54].

For the state of the extensor

Do this test only when there is no flexion contracture. Steady the thumb by holding it by the metacarpal and the proximal phalanx, and ask the patient to lift the thumb. When the extensor pollicis longus muscle is weak or if its tendon is damaged over the IP joint and if there is no flexion contracture, the terminal phalanx cannot be lifted fully into the straight or the hyper extended position. Measure the extent of “extension lag” and record it as an “assisted extension angle” or as an “extension lag” by so many degrees [54].

ASSESSMENT OF THUMB WEB

Let the patient place the hand on the table, resting on its ulnar border and palm facing one side, and hold the hand steady. The thumb is taken hold by its metacarpal head, not by the proximal or distal phalanx, and move it passively off the plane of the palm and across it (i.e., abduct and make the thumb oppose) as much as possible, stretching the thumb web in the process. Measure the angle between the shafts of the metacarpal bones of the thumb and the index. The measurement gives the “passive abduction’ or “thumb web” angle. When this angle is less than 40°, it indicates thumb web contracture. Such patients should be referred to a specialist center. Corrective surgery without correction of thumb web contracture is sure to fail [10].

RESTING POSITIONS OF THE THUMB

Normally, the thumb lies in a plane in front of the palm, its metacarpal diverging away from the palm by 15–20° and the phalanges pointing forward (the MCP joint is flexed by about 20–25° and the IP joint is straight). When all the intrinsic muscles of the thumb are paralysed as in combined paralysis of ulnar and median nerves, the thumb falls back and is more or less on the same plane as the palm, its metacarpal diverges more than normal, the MCP joint is more flexed than normal and the IP joint is flexed by 50° or more [55].

Thus the thumb lies hyper extended at its basal joint and flexed at the middle and distal joints, like the claw finger. This is the “paralytic claw thumb” deformity present when all the intrinsic muscles are paralysed. When there is only ulnar nerve paralysis and when the flexor pollicis brevis muscle is completely paralysed the thumb shows a characteristic resting posture in which, the CMC joint position is normal, but the MCP joint is straight so that the proximal phalanx now lies in the same line as the metacarpal, or it is hyper extended and the IP joint is flexed by 15–30° [54].

Scoring Systems for Thumb Function*

Scoring systems for assessing thumb function play a crucial role in clinical evaluations, providing standardized measures to gauge various aspects of thumb movement and strength. These tools are essential for diagnosing conditions, planning treatments, and tracking patient progress.

Kapandji Score: Developed by I. A. Kapandji, this system evaluates thumb opposition by assessing the ability to reach specific landmarks on the hand. [56]

Michigan Hand Outcomes Questionnaire (MHQ): While comprehensive for overall hand function, the MHQ includes subscales specifically addressing thumb-related activities, such as pain, daily tasks, and satisfaction with function. [57]

Jebson-Taylor Hand Function Test: Originally designed for assessing hand function in stroke patients, this test includes tasks that also evaluate thumb function, such as picking up small objects and simulating feeding tasks. [58]

4.DASH (Disabilities of the Arm, Shoulder, and Hand) Score*: A widely used measure encompassing items related to thumb function, including writing, gripping, and performing daily activities. [59]

5.Jebsen Hand Function Test*: This assessment includes tasks such as writing and manipulating small objects, providing insight into thumb function alongside overall hand performance. [58]

These scoring systems vary in complexity and applicability, catering to different clinical needs and research objectives. Selecting the appropriate tool depends on the specific aspects of thumb function being evaluated, such as range of motion, strength, coordination, and overall functional capabilities.

Table (1): Kapangi score [60]

CORRECTIVE SURGERY FOR PARALYTIC CLAW THUMB

As mentioned above, the thumb is unable to abduct (lift itself off the palm) because of the paralysis of abductor pollicis brevis and rotate inwards whilst in abduction to face the fingers [oppose] because of the paralysis of opponens pollicis. If flexor pollicis is also paralysed then this also has to be restored otherwise when the thumb comes into contact with the opposing fingers against resistance it will collapse into supination and opposition will be lost (the Crank Handle effect) [61].

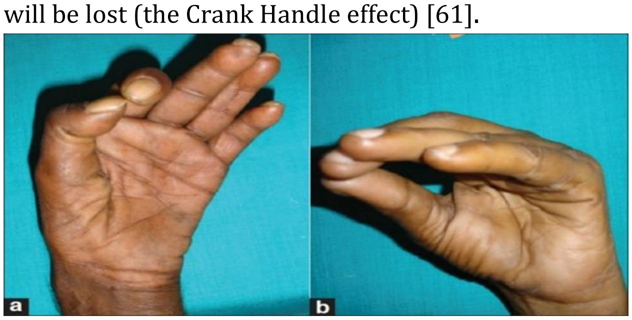


Figure (5): (a) When FPB is not acting "Crank Handle effect". Note the index finger on attempted opposition. Collapses the thumb into supination. (b) Normal FPB resulting in good opposition with pronation [54].

In low median palsy, the muscles involved are abductor pollicis, opponens pollicis and flexor pollicis if supplied by median [62].

Abduction, opposition and pronation are lost resulting in loss of pinch. If the FPB is paralysed or weak the MP joint goes into extension and the IP joint goes into flexion. Abduction and opposition are to be restored, FPB is required to oppose against forces like ulnar fingers or objects and the thumb must pronate [54].

For convenience of understanding, we can divide these into three variables [63]:

• The motor.
• The pulley (this changes the direction of the line of pull).
• The insert.

All the muscles supplied by ulnar and radial nerves and median supplied extrinsics are available for transfer in low median palsy [64].

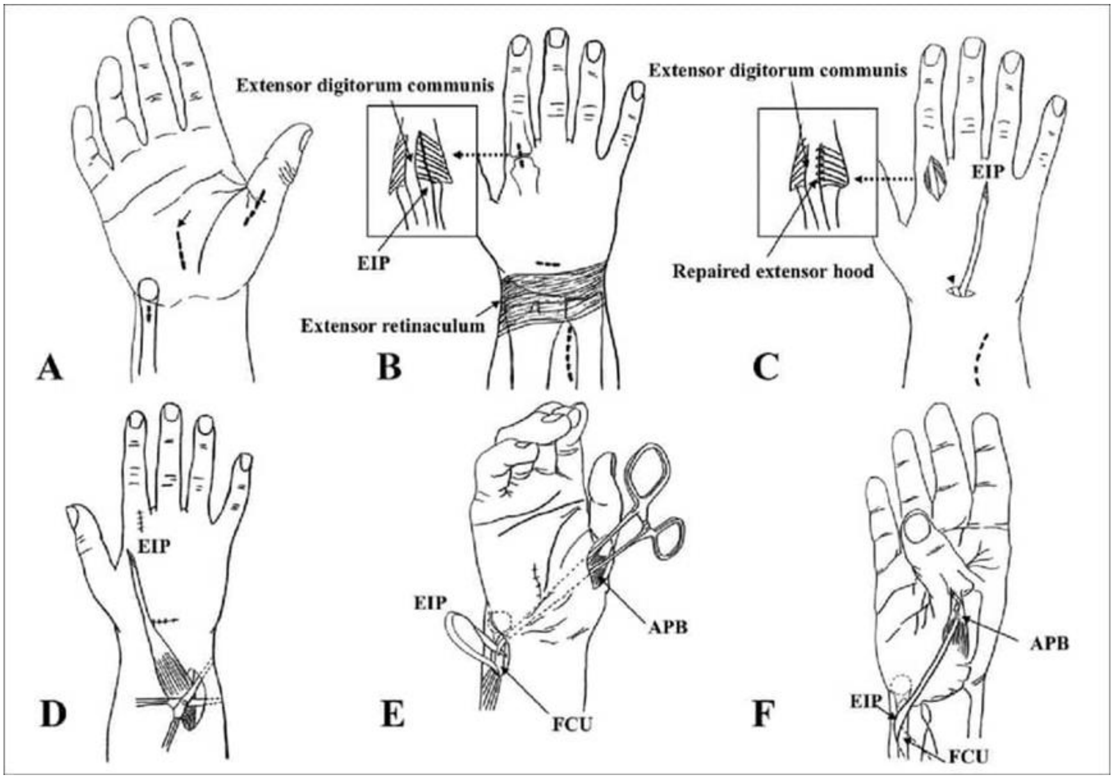
The motors which are commonly used are [65]:

FDS of the ring finger.

ECU extended on a graft.

Ext. Indicis Proprious.

Palmaris Longus extended with palmar aponeurosis.
Abductor Digiti Minimi.
The most commonly used motor is FDS of the ring finger. This has adequate length and hence does not require any extension, powerful and easy to perform. However if the patient has hyper mobile finger then, the loss of PIP flexor may result in Swan Neck deformity, which is a difficult deformity to correct. We must also remember that a good percentage of Indian patients have hyper mobile fingers [54].



Fig(6):an illustration of opponensplasty using Extensor indices tendon [66]
ECU is a phasic transfer and will yield good result. Electrical activities are noticed in ECU during normal opposition movement. However if there is an associated high ulnar lesion where in the FCU is paralysed and if we remove ECU also then the wrist may go for radial deviation due to unopposed action of FCR, ECRL and ECRB [64].
EIP is an easy transfer to perform but since the tendon is thinner and power is less it is better to use it when the flexor brevis function is present and thumb extensor is also not weak. It is ideal wherein we need to replace only abduction rotation. The donor site hood must be meticulously repaired. I do not prefer Palmaris, as it may be useful as a graft or for some other transfer if necessary. This also needs an extension. Abductor Digiti Minimi gives good aesthetic result, but it may not be available when there is associated ulnar palsy too. Half FPL, Split EPB to ECU are some of the other uncommon transfers which are used in selective cases [54].
PULLEY CREATION
Once we have chosen the motor then we have to route it to thumb from the direction of pissiform bone. This necessarily means we need a pulley, which will change the direction of pull and maintain it in that position [67]. Various pulleys are used for this purpose. The common ones are [54]:
Sub-cutaneous pulley around pisiform.
Guyon's canal.
Half FCU turned as loop.
Through the distal part of flexor retinaculum.

Around Lower end of ulna.
Sub-cutaneous tunnel if not taken deep may slowly migrate and loosen the tension over the years. If ulnar nerve is not involved it may be risky to tunnel through Guyon's canal for fear of injury, otherwise it is an excellent pulley. Gliding may not be good in flexor retinacular window. If we are using ECU or EIP then the lower end of ulna is ideal, as it has to curve around it from the extensor side to reach the thumb. One-half of the distal 2–3 cm of FCU can be cut attached distally to pissiform and can be turned to be sutured onto itself as a loop or to nearby ECU and this will serve as a good pulley. I will either use FCU or deep sub-cutaneous pulley [68].
CHOOSING THE PULLEY
We choose the pulley depending on the line of pull required and it is dictated by the presence or absence of the FPB function. If FPB is acting and only APB is paralysed then the line of pull is logically to be in line with the axis of APB. But if both FPB and APB are not acting, then the direction of pull must be in line with the vector between these two muscles. Therefore, I choose a proximal pulley like ulna, Half of FCU, mouth of FCR tunnel for the former and a distal or palmar side pulley like Guyon's canal, around pissiform for the later [69].

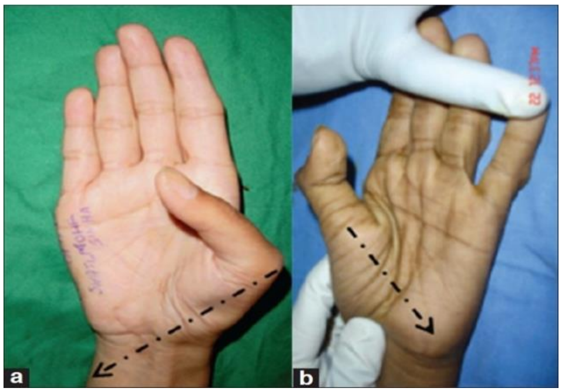


Figure (7): (a) FPB present and axis of pull should be along mid-axis of APB. (b) Both FPB and APB are paralysed—axis of pull should be between APB and FPB [70].

Basic steps as algorithm is [54]:
- Choose a motor.
- Route it from the ulnar direction so as to abduct (minimum).
- Select a pulley as described.
- Optionally one slip must travel volar to the MCP joint of thumb for acting like FPB.
- Inserted distally on extensor side of IP to keep IP straight.

STEPS OF A TYPICAL FDS TRANSFER
Under axillary block the transfer can be done. An incision is made on the radial side of the ring finger proximal PIP region in the neutral line and deepened. Flexor sheath is exposed and incised. The radial slip of FDS is held with a haemostat and divided close to its insertion. When we pull at this slip, the ulnar slip will emerge out and it can also be divided after holding with a haemostat. Next the two slips must be separated until the decussation so that it does not get caught by the FDP, when pulled out into forearm. An incision is made proximal to wrist and medial to the FCU, the FDS can be easily identified by pulling at the distal end held by haemostat and delivered into the forearm wound. Sometimes when we pull at the tendon, we will notice that the little finger is moving and the tendon cannot be delivered. In such a situation, separate any connections between the two tendons in the forearm. If still we are unable to deliver then we must open the palm and look for any connections between FDS of the ring and little fingers and divide them [71].
Next an incision is made just distal to the pissiform bone in the palm and the incision deepened to expose small globules of fat suggestive of Guyon's canal. By inserting a tendon tunneller deep through the canal, the FDS slips are pulled through the canal distally [54].

Next three incisions are made in the thumb. The first one is made in the radial side of the thenar area in the middle of first metacarpal along one of the creases, the second longitudinal incision on the ulnar side of dorsum of the thumb in the region of the MP joint of the thumb for 2 cm, and the third incision is made over the dorsum of proximal phalanx just proximal to the IP joint [72].

The two slips are tunneled to the thenar wound. Here they are separated for about 5–6 cm. The proximal slip is passed to the ulnar side and the distal one passed to the dorsal incision keeping the MP joint in 60° of flexion and passing the tendon volar to the axis of the MP joint. Now the hand is positioned with the wrist in a neutral position, the thumb in 80° of abduction and rotation, the MP joint in 30° of flexion and the IP joint in a straight position. The proximal slip is passed around the Add.Poll.Brevis and pulled and fixed maintaining the position. Suturing is also done to the MP joint capsule. Tension is given by pulling the tendon for about 1 cm after taking the slackness off. The second slip is sutured to the EPL without tension. After the suturing, the position must remain as it is after leaving the hold on to the thumb. Skin is closed and POP is given keeping the thumb in an abducted, opposed position with MP flexed at 30°, IP straight and wrist in minimal flexion [54].

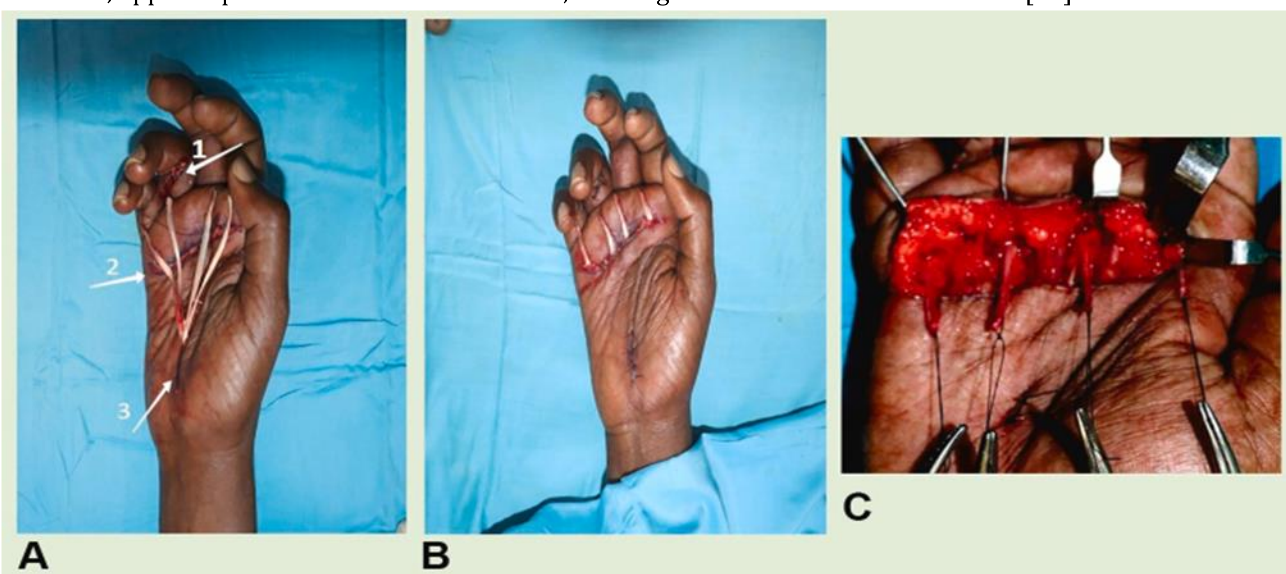


Figure (8):The Zancolli lasso procedure. A FDS of the ring finger split into 4 slips. Arrow 1 shows an oblique incision on the proximal phalanx of the ring finger to remove FDS insertion. Arrow 2 shows a transverse incision on the distal palmar crease. Arrow 3 shows a longitudinal incision on the palm, distal to the carpal tunnel. B FDS slips taken out from the incision at the distal palmar crease. C FDS slips after manipulation over the A1 pulley. [73].

HIGH PALSY

Additionally, we need power to FDP of index and middle fingers and FPL. If the power in little and ring fingers are good and the patient does not require more precision we can tag the radial two finger tendons to the ulnar fingers. If needed, we can transfer ECRL to FDP and Brachio radialis to FPL [74].

POST-OPERATIVE MANAGEMENT

The splint is maintained for 3 weeks and then discarded. Sutures also can be removed during this time if we use fine monofilament material [75].

Gradual active mobilization is given in the first 2 weeks after discarding the splint keeping the MP joint in 30° flexion and encouraging movements within this. In the third week purposeful movement like holding pen, etc. can be given and during the fourth week he can use the hand for eating. However, heavy manual work should not be done for another 2 months [54].

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