WORKSHOP REPORT

Re-enablement of the neurologically impaired hand – 2: surgical correction. Report of a Surgical Workshop held at Green Pastures Hospital and Rehabilitation Centre, November 2004, Pokhara, Nepal

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Introduction

In a separate paper (see this issue) the authors discussed non-surgical aspects of the neurologically impaired hand as frequently seen in people affected by leprosy neuropathy. These aspects included applied anatomy, terminology and assessment. An adequate understanding of the neurologically impaired hand, and its primary and secondary impairments, is necessary to be able to judge how specific surgical interventions may affect the functioning of the hand. It was also concluded that to be able to fully ‘value’ the effects of reconstructive procedures, the assessment and evaluation of interventions should be at the three levels of human functioning: impairment, activity and participation.¹

It is recommended that the reader is familiar with the material discussed in the companion article to this paper.²

In this paper, the common surgical procedures are discussed. The procedures for uncomplicated neurologically impaired hand with paralysis of ulnar, median or radial nerve paralysis will be discussed first, followed by surgical interventions for the impairments that may have developed secondary to the paralysis or the surgery. Recommendations for best practice and further research will be given.
Primary impairments

The most commonly affected nerve in the upper extremity is the ulnar nerve, followed by the median nerve. Median nerve palsy usually presents with associated ulnar nerve palsy, but can occur in isolation. Radial nerve palsy is relatively rare. When present, it is usually part of a ‘triple palsy’, impairment of ulnar, median, and radial nerves. High median nerve impairment and the occurrence of the so-called flail hand, that is, the hand without any intrinsic or extrinsic muscle function, is extremely rare and will not be discussed.

Ulnar nerve palsy

In leprosy affected nerve-impaired hands, dynamic correction (tendon transfer) procedures are the operations of choice to correct the claw deformity. Static corrections should only be considered when there are no active muscles available, e.g. in triple/high median nerve palsies. A pulley advancement or Srinavasan’s extensor diversion would be preferred static techniques, as they have less likelihood of recurrence of deformity than a metacarpophalangeal (MCP) joint capsulodesis. When performing tendon transfers, the surgeon should consider the type of hand and the severity of impairments and choose the most appropriate procedure, rather than performing the same procedure for all patients. All secondary impairments should preferably be corrected prior to the procedure, although not always will all secondary impairments be correctable. The exception is ‘hooding’, which can be corrected at the same time as the intrinsic replacement procedure. Mild hooding, less than 20–30 degrees short of active-assisted extension, can often be overcome by prolonged serial casting.

RECOMMENDED PROCEDURES

For the hypermobile hand, we recommend a palmaris longus to pulley or lateral band insertion or a transfer of the extensor carpi radialis longus (ECRL) to the A1-2 pulley insertion. We refer to the study by Lee and Rodrigues for a discussion about the relative advantage of various insertion sites of a transfer.

For the mobile hand that does not extend beyond neutral in active assisted-extension, we prefer a lateral band insertion or a flexor digitorum superficialis (FDS) insertion to the pulley. The technique of harvesting the FDS tendon may influence the risk of post-operative complications in the donor finger, such as swan-neck and check-rein deformities. Existing evidence would suggest that a palmar approach is associated with a lower rate of donor finger complications than a lateral approach. The FDS can be easily and safely harvested through the palmar incision during a FDS to pulley insertion procedure. Duerksen recommends a tenodesis of the FDS stump to the A2 pulley to prevent swan-neck. He also stresses the need for good haemostasis when the vinculae are transsected. (Duerksen, personal communication).

For the stiff hand, with mild contractures present, we recommend an ECRL or FDS to lateral band insertion. Technically, the ECRL transfer requires more skill but the FDS may leave a defect in the donor finger. The FDS, however, is the stronger muscle. Both are easy to re-educate.
For fear of compromising the median nerve in the carpal tunnel, some surgeons prefer to stay on the extensor side of the wrist when tunnelling an extrinsic tendon to the fingers in an isolated ulnar palsy. Brand has shown that there is ample space in the carpal tunnel to accommodate an extra tendon. When the tunnelling is done in a correct manner this fear seems to be unjustified. Some surgeons add a fifth slip to the thumb for correction of thumb interphalangeal joint hyperflexion, or into the metacarpal head of the little finger to correct the loss of the metacarpal arch. In each case, the additional slip acts on a joint with different moment arm and different excursion, and in the case of the extra slip to the thumb, a very different direction of pull. Biomechanically, the value of these additional transfers is questionable and they may compromise the function of the intrinsic replacement. No research has been done to assess the effectiveness of either addition. An additional slip to the thumb is not recommended, and the effect of adding a slip to the fifth metacarpal needs to be properly assessed.

RESEARCH

More studies are needed comparing the different procedures to correct claw finger deformity to find out the relative (dis) advantages given the pre-operative condition of the hand. The FDS of ring and middle fingers are important potential donor muscles in ulnar and median nerve palsy. In a large number of patients, removal of the FDS results in a defect on the donor finger. When should the FDS not be removed? What can be done to prevent or correct a defect? Does the incision and method of harvesting the tendon have a bearing on the incidence of a secondary defect?

Little is known regarding how intrinsic paralysis effects grip/pinch strength and to what extent the strength of the hand is affected by the various tendon transfer procedures. Often a better grip/pinch function is expressed by the patient as better/improved strength because the grip is more secure and pinch activities are restored. Is grip strength related to the muscle used, its relationship to the wrist axis and insertion?

Early mobilization of flexor tendon repairs following traumatic lacerations is common practice. Following tendon transfers the hand/fingers are commonly immobilized for 3 weeks in a cast. Some centres, however, now open the plaster cast after a few days, leaving a slab, and begin mobilization. The effect of early mobilization on time to discharge and end result needs to be assessed.

How does the dorsal versus volar approach of wrist extensor to fingers effect the metacarpal arch and grip strength? Some research has been done in this area.

The effect of tendon transfers in ulnar palsy on the ability to perform activities of daily living needs to be researched.

The thumb in ulnar palsy

Ulnar nerve palsy causes paralysis of the first dorsal interosseus, the adductor pollicis and often the flexor pollicis brevis. The two basic impairments seen in the thumb in ulnar nerve palsy are a marked decrease in strength of the key pinch and in the pulp-to-pulp pinch (due to paralysis of adductor pollicis, first dorsal interosseus and flexor pollicis brevis).
RESTORATION OF KEY PINCH (ADUCTION)

Little is known about the effects of restoration of adduction loss in ulnar nerve palsy. What is known is that restoration is not commonly practised. Two studies have reported an increase in key pinch strength, but no functional outcomes have been measured.\textsuperscript{42,43} Many surgeons support the use of a FDS to adductor pollicis transfer in ulnar palsy.\textsuperscript{42–45} The ECRB transfer described by Smith has the real disadvantage of sacrificing the principle extensor of the wrist.\textsuperscript{42} Smith stopped using this transfer after he had described it (personal communication). Both the ECRB and FDS transfers for restoration of adduction have the disadvantage of a near 90-degree turn in the transferred tendon, putting it at a mechanical disadvantage. Fisher \textit{et al.} reported the use of ECRL for adductor replacement. They used the APL to substitute for the loss of the first dorsal interosseus.\textsuperscript{46}

RESTORATION OF PRIMARY THUMB MCP FLEXION

In many cases of ulnar nerve palsy, the loss of primary thumb MCP flexion will lead to interphalangeal (IP) joint hyperflexion (Froment’s sign), sometimes combined with MCP hyperextension (Z-thumb). This is a significant deformity, as the contact surface of the thumb becomes the nail rather than the pulp, leading to an unstable grip and the risk of self-injury.

RECOMMENDED PROCEDURES

Often in combined ulnar/median nerve palsy, the two-tailed opponensplasty will correct the deformity. If surgical intervention is indicated, four options are available.

\textit{MCP arthrodesis}. This is recommended for a stiff or severely hyperextended Z-thumb (Figure 1).\textsuperscript{15}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{thumb_deformity.png}
\caption{Severe Z-deformity of thumb.}
\end{figure}
Half of flexor pollicis longus to extensor pollicis longus transfer. This is recommended for a mobile Z-thumb.12,47

IP arthrodesis. This procedure is recommended when there is a fixed flexion contracture of the IP joint.

Adductor replacement as described above. This could be considered in the mobile thumb.48,49

RESEARCH

The possible benefits of adductor replacement for the thumb in ulnar nerve palsy need to be researched with special regard to the functional outcomes. When should an adductor replacement be used?

Which surgical techniques should be employed to give the best outcome given the primary and secondary impairments?

Median nerve palsy

Loss of opposition is a very significant functional impairment, although in pure median nerve palsy opposition is often adequately preserved, especially when the flexor pollicis brevis is entirely innervated by the ulnar nerve. In cases of isolated median palsy without adequate functional opposition, palmaris longus transfer should be considered.50 In combined ulnar/median nerve palsies reconstructive surgery is always indicated. Secondary defects, such as web space and joint contractures, need to be dealt with prior to or at the time of surgery.

RECOMMENDED PROCEDURES

Extensor indicis proprius (EIP) and FDS transfers are both considered good options in pure median nerve palsies.4,51–55 In combined ulnar and median palsy, the Brand two-tailed FDS transfer is recommended to assist in interphalangeal extension.38,56,57 An EIP or extensor pollicis longus (EPL) transfer, often in combination with a half flexor pollicis longus to EPL transfer, is also an option (Figure 2).38,59 Attachment of the transfer to the radial side of the joint capsule produces good abduction but insufficient rotation for pulp-to-pulp pinch activities.

Figure 2. Extensor pollicis longus transfer (From: Schwarz and Brandsma, Surgical rehabilitation in leprosy and other neuropathies. EKTA, Kathmandu, 2004).
Guidelines for indications for opponensplasty in isolated median palsy need to be developed. A study, comparing the commonly available techniques for opponensplasty in isolated median nerve palsy is needed.

Guidelines are needed for indications for tendon transfers in combined ulnar and median palsy given the presence of possible underlying secondary impairments.

**Triple palsy**

This is an uncommon but serious impairment. The typical pattern is a high ulnar/high radial and low median nerve palsy. Sometimes there will be high median nerve impairment in which case there will not be any muscles available for transfer. Some patients may not be candidates for surgery due to a lack of motivation or a severe deficit with associated secondary deformities. This condition can be managed surgically in two sessions as follows.60–69

**RECOMMENDED PROCEDURES**

In the first stage, the PT is transferred to ECRB and yoked to the ECRL, and re-routed to the base of the ring metacarpal. The FCR is transferred to the EDC, possibly also the EPL. Alternatively, the PL could be transferred to dissected and re-routed EPL.

In the second session, the FDS of the long finger is transferred to the lateral bands of the fingers and the FDS of the ring finger is used for opponensplasty. Yoking of the re-routed ECRL to ECRB for the pronator teres transfer is strongly recommended, as there is a significant risk of radial deviation if the pronator teres is attached to the ECRB alone.38,70,71 The FCR transfer also has a tendency to cause radial deviation. A wrist arthrodesis is almost never indicated. This may reduce the function of the hand but rarely the power, as the wrist is now stable in a functional position. If available, primary wrists moving muscles could be used to further enhance the function of the hand.68,72,73 In a severely paralysed hand, a hinge-hand procedure may often give a better result than an arthrodesis as it allows the tenodesis effect of wrist flexion on finger extension and vice versa.74–76

**SECONDARY IMPAIRMENTS**

Secondary impairments can develop as a result of primary impairments, primarily muscle imbalance and loss of protective sensation. Basic exercises and life style changes can too a great extent prevent these from happening. Secondary impairments may also follow certain reconstructive procedures.

The hand without secondary impairments is potentially the best hand for a successful outcome of tendon transfer surgery. The general principle with these impairments is to *Avoid*, *Recognize* and *Treat*.

The secondary impairments can in almost all instances be *avoided* by early diagnosis of leprosy, appropriate health education, therapy and timely surgery for primary impairments if indicated.77 Secondary impairments must be *recognized* quickly before they progress to a point
of irreversibility or serious functional loss. Finally, they should be treated appropriately as outlined below.

**Joint contractures**

Longstanding ulnar nerve palsy with clawing can lead to contractures of collateral ligaments, volar plate and joint capsule of the PIP and, less often, the DIP joints (Figure 3). Prevention of contractures, involving ‘passive’ and active-assisted exercises after the diagnosis of ulnar palsy, obviously gives superior results to treatment after they are established. For the ‘mobile’ hand, that is the hand with full assisted extension, active-assisted extension exercises will suffice to prevent contractures. When contractures are present, ‘passive’ extension exercises are needed to overcome the contractures. Depending on the severity of the contractures this may be supplemented with serial casting or other splints. The splinting can be carried out with either serial plasters, a thermoplastic splint, or the JESS (Joshi External Stabilising System). Once splinting shows no progress over a period of 2 weeks, it is unlikely that any additional benefit will be seen. At this point surgical options should be considered. Severe contractures will not infrequently be seen in patients with poor motivation, and so an evaluation of the patient’s motivation for surgery must be made before embarking on any of these procedures.

**PIP joint contracture**

The PIP joint contracture is the most common contracture associated with clawing. If therapy fails to fully extend the joint, and the joint can still fully flex, attempts should be made to carry out a soft tissue release rather than an arthrodesis. A mobile moderately contracted PIP joint

![Figure 3. Moderate contractures of ring finger and severe contracture of little finger.](image-url)
is more functional than a fixed one. A ‘mobile’ contracted joint refers to a joint which has an extension loss on passive extension but still has a reasonable range of motion into flexion.

RECOMMENDED PROCEDURES

A skin and lateral ligament release as described by Fritschi can be very effective, or a local flap can be used to cover the skin defect. Gradual distraction with the JESS system has reported good results (Figure 4). The JESS system when taking special precautions can be used safely on the neuropathic hand. Once the contracture has been maximally released, the intrinsic replacement should be done using the FDS from the contracted finger, if still contracted, and transferred to the lateral bands to maximize PIP extension. Dorsal fixation of the lateral bands may have to be carried out as well.

PIP joint arthrodesis in a functional position should be considered in severe fixed joint contractures that fail all attempts at release. The angle of fixation needs to be discussed with the patient and depends on hand usage. Occasionally amputation at the PIP joint will give equivalent results to arthrodesis.

RESEARCH

A comparison between the JESS system and present conventional techniques such as serial casting and exercises needs to be done. Outcome measures should specify complications, cost, patient acceptance and time to correction of deformity.

Figure 4. Bilateral single JESS (From: Schwarz and Brandsma, Surgical rehabilitation in leprosy and other neuropathies. EKYA, Kathmandu, 2004).
DIP joint contracture

A severe DIP contracture may cause functional problems with grasp and pinch and is, in an insensate hand, a risk factor for ulceration. Soft tissue releases are generally inadequate, and arthrodesis is recommended.

Thumbweb contracture

Thumb web contractures should be prevented by simple exercises. When present and mild, the contracture can be overcome with simple exercises and splinting.

Severe contractures will require surgical intervention, with either a Z-plasty and/or a dorsal release and skin graft. The most severe types may require a dorsal flap webplasty.

Carpometacarpal joint disorders

The thumb carpometacarpal (CMC) joint (trapezio-metacarpal joint) is the key joint for thumb function. This is the joint where opposition occurs. Encountering any pathology in this joint with pure median palsy is unlikely. It may happen in ulnar palsy and is often seen in long-standing, combined, ulnar and median palsy. Two pathologies can be seen.

CONTRACTURE OF THE CARPOMETACARPAL JOINT

This is common, and associated with longstanding ulnar-median palsy leading to repositioning of the thumb and shortening of the carpometacarpal ligaments. This can cause restriction in opposition and may be associated with first web space contracture and dorsal skin deficiency. If this fails to respond to therapy, surgical release is indicated prior to opponensplasty.

CARPOMETACARPAL DISLOCATION

This condition is often unrecognized but is reported in 20% of ulnar/median nerve palsy hands. It is possible that under-recognition is a cause of some failed opponensplasties. Various techniques have been described. CMC joint arthrodesis is not recommended, as it is likely to cause an even greater impairment.

Capsular reconstruction as described by Eaton is highly successful and causes no joint limitation problems (Figure 5). A good repair will put the thumb in a more abducted position.

RESEARCH

Guidelines are needed for better assessment and understanding of thumb carpometacarpal disorders. These are needed to able to better evaluate and compare the outcome of various surgical procedures to correct thumb CMC disorders.
PIP extension deficit (hooding deformity)

The cause for ‘hooding’ is attenuation of the central extensor tendon, either from longstanding clawing or from trauma on the dorsal PIP joint and exposure/necrosis of the central tendon. In longstanding cases a PIP joint contracture may develop. A Boutonniere deformity is a more severe presentation of this condition, and is essentially a hooding deformity with a fixed distal inter-phalangeal joint extension contracture.

RECOMMENDED PROCEDURES

The hooding deformity is well treated by the dorsal fixation of the lateral band procedure, which can be carried out at the same time as the intrinsic reconstruction. Other options would be reconstruction of the central tendon (more likely to fail) or a lateral band crossover. In a Boutonniere deformity it is important to first correct the joint contractures with therapy. When correcting the clawing deformity, if a Boutonniere deformity is present in the ring or
middle finger, it is recommended to use the FDS from that finger as the donor tendon. Surgical release of the contracted DIP joint may also be indicated.

**Research**

The incidence of hooding/boutonniere deformity in intrinsic paralysis and its independent functional effects are unknown and the long-term effects following correction need to be further researched.

**Finger flexor tightness**

In longstanding clawing, the chronic flexed position of the fingers can lead to shortening of the long flexors of the fingers. Usually this responds well to splinting (preferred) and exercises. Some hands will require many months of therapy to attain full muscle length. These patients may be best served with fascia and aponeurosis release.96,97

**Research**

- A method of quantifying the degree of extrinsic finger flexor tightness needs to be developed.
- When are exercises/splinting indicated or is surgery needed to overcome severe flexor tightness and to what extent does flexor tightness interfere with the outcome of intrinsic replacement?
- Can the intrinsic replacement procedure be carried out concomitant to the aponeurosis release? If not, what time gap is required?

**Minus or mitten hand**

This condition is defined as a hand with severely shortened digits, especially the thumb (Figure 6). Malaviya has graded this condition according to severity and degree of thumb involvement.98 This serious deformity comes from many years of neglect and fortunately is seen much less commonly now. This is the most obvious example of the adage ‘prevention is better than cure’, as truly there is no cure for this condition. Certain interventions however can ameliorate the functional deficits these patients have.

A thorough assessment is required of both hands and feet, the patient’s motivation and what their required functional limitations are. Patients with this severe a deformity tend to have low motivation so interventions should be kept simple. In most cases various hand orthoses can be made to enable the patient to carry out the needed activities of daily living (ADL).99 These are custom-made from self-hardening putty such as Modulan (Ciba-Geigy).

Surgical interventions should generally focus on the thumb, as the majority of hand functions involve the thumb.100 If the entire proximal phalanx is present, usually no lengthening procedure is indicated.

**Recommended procedure**

Phalangization of the thumb metacarpal is indicated if less than half of the proximal phalanx is present.101,102 This is best done by a deep Z-webplasty, or better by a dorsal flap webplasty. Following phalangization, a tendon transfer may be indicated to enhance pinching.
For more proximal degrees of loss, a finger transfer may be indicated. Gillie’s procedure, while recommended in the past, has a high complication rate. If no phalanges are present a second metacarpal transfer may be indicated. Osteocutaneous flaps based on the radial or the posterior interosseus arteries may be suitable in some centres. For hand loss up to the wrist level, a Krukenberg operation may provide functional benefit.

First webspace wasting

This is almost universal in ulnar nerve palsy. In many societies it does not appear to be a problem, but in some societies cosmetic concerns lead to many patients requesting correction.

Dermal grafts, although tedious due to the large amount of dermis required, have a good success rate whereas fat grafts have a strong tendency to resorb. Silicone implants, especially of the gel capsule type, have a good cosmetic appearance, are technically easy to carry out, and have a low complication rate.

Secondary impairments related to surgery

DEFECTS ON DONOR FINGER WHEN FDS IS USED

Check-rein

This presents as a fixed PIP joint flexion contracture and is caused by adhesions from the FDS stumps to the flexor tendon sheath with subsequent scar contracture. Anderson reported an 8% incidence using a lateral FDS removal incision vs 0% when a palmar approach
was used. Brandsma reported 26% in his series. Prevention is again the best policy, with early post-operative exercises, gentle PIP joint extension, and immediate night splinting once the complication is detected. Once established, surgical release is indicated, but this has a high incidence of recurrence.

**Research** A better understanding of check-rein deformity is needed. When is it likely to develop and how can it best be prevented or corrected if established?

**Swan-neck**

Also known as FDS-minus or intrinsic plus finger, it presents as PIP extension with DIP flexion. It can be a very disabling deformity. It was seen in 44% of cases using a lateral FDS harvesting incision vs 8% using a palmar incision in Anderson’s series. The deformity will be very common in hypermobile hands if the FDS is used as a donor tendon, and as such an FDS transfer in a hypermobile hand is contraindicated. Implantation of the FDS stump into FDP or the flexor tendon sheath at the time of transfer has been proposed to prevent this complication but a comparative trial has not been done. In mild cases only passive flexion exercises are indicated.

**Recommended procedures** If fixed deformities have developed, Littler’s procedure (excision of a triangle of oblique fibres at the mid proximal phalangeal level) may be indicated. Other procedures, such as lateral band re-routing or lateral band distal slide may give better results.

**Research** Existing approaches for the prevention of swan-neck deformity need to be more widely implemented. Better techniques for treatment of established swan-neck deformities may need to be developed.

**DIP joint hyperflexion**

Hyperflexion of the DIP joint is commonly seen after FDS removal and is essentially a mild form of the swan-neck deformity. Sometimes this deformity is referred to as a profundus plus deformity. It is generally not a significant functional problem. Methods of prevention and treatment are similar to those described under swan-neck deformity.

**Summary**

The last half-century has seen tremendous advances in the surgical treatment of neuropathic conditions of the hand. Many of these procedures give clear benefit to patients and have been established by clinical practice and well-formulated assessment. However, much remains to be discovered, especially with respect to which procedures should be used on which hands, and the impact of various procedures on the ability to carry out activities of daily living. Increased communication between the ‘West’, where funding is available for well designed trials and where reference textbooks are usually published, and the ‘East’, where the surgery is most commonly performed, will undoubtedly lead to an even better understanding of the treatment of the neuropathic hand.
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References

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