



Clinical Case of the Month

Reconstructive hand surgery

A Ejeskär^{*1}, VR Hentz², F Holst-Nielsen³, MW Keith⁴ and AG Rothwell⁵

¹Department of Hand Surgery, Sahlgrenska University Hospital, Göteborg, Sweden; ²Stanford University School of Medicine, Stanford, California, USA; ³Ortopedkirurgisk afdeling, Rigshospitalet, København, Denmark;

⁴Department of Orthopaedics, MetroHealth Medical Center, Cleveland, Ohio, USA; ⁵Department of Orthopaedic Surgery, Christchurch Hospital, Christchurch, New Zealand

Case report

A man born in 1960 sustained a cervical cord lesion and a complete tetraplegia in a diving accident in 1990. On examination in October 1996 his muscle function was as follows right/left: triceps 0/2, biceps 5/5, brachioradialis (BR) 4/5, extensor carpi radialis longus (ECRL) + extensor carpi radialis brevis (ECRB) 4,5/4,5, pronator teres 4/4, flexor carpi radialis (FCR) 0/2, extensor digitorum V 1/2. He had a 2-point discrimination of 5 mm in both thumbs and left index finger.

Both his thumbs had a rather flexed position making the tip of the thumb meet the top of the long finger so making it difficult for him to use a spontaneous key grip. After the injury he became left-handed and he now wishes to get better hand function in both hands.

- 1 What is your classification of the patient's arms?
- 2 What is your plan of treatment?

First comment: VR Hentz

Classification

I would, according to the international classification¹ (Table 1), classify this patient's right and left arm as OCu:4, triceps negative. However, because this patient has a grade 2 FCR he will function more like an OCu:5 on the left side. In my experience a grade 2 FCR is a functionally useful FCR provided that the shoulder is good and that good pronation and supination of the forearm is possible.

Treatment plan

The motor resources for this patient would certainly permit consideration for reconstruction of active grasp and pinch and active elbow extension for both limbs.

For his left upper extremity I would consider deltoid to triceps transfer, and having completed that do the extensor phase of the procedure described by House.² It has been my experience that digital extension, particularly if some wrist flexion is present, is better accomplished by tenodesis rather than by trying to strengthen a very weak but present extensor digitorum communis muscle. At the same time I would perform a split flexor pollicis longus (FPL) insertion as described for the tetraplegics.³

After a period of rehabilitation I would perform the flexor phase as described by House.² This includes transfer of the BR for thumb flexion/abduction, PT to FPL, and ECRL to the digital flexors with, in addition, a side-to-side flexor digitorum profundus (FDP) tenodesis reversing somewhat the normal cascade. Depending upon the status of the extensors and, in particular, the effectiveness of the extensor across the proximal interphalangeal joint I would consider either a Zancolli lasso⁴ or the intrinsic substitution procedure described by House.² This latter procedure involves a strip of tendon anchored to the middle phalanx of the index finger brought along the course of the interosseus muscle deep to the transverse metacarpal (intervolar plate) ligament. It then passes deep to this ligament out to the same attachment on the middle phalanx of the middle finger. A similar tendon graft is used to perform the same procedure for the ring and little finger. One should anticipate between 2–4 kg of pinch strength and 8–10 kg, or greater, of grip strength following this procedure in this individual's left hand.

For the right hand, I would consider posterior deltoid to triceps transfer combined with fusion of the thumb carpo-metacarpal (CMC) joint in an appropriate position, split FPL tenodesis, BR to FPL transfer, tenodesis of the extensor pollicis longus (EPL) to the retinaculum. I would search for an extensor carpi radialis intermedius tendon or muscle slip that I might pass through the interosseous membrane to weave into the superficialis finger flexors. I would then open the first annular ligament

*Correspondence: Dr A Ejeskär, Department of Hand Surgery, Sahlgrenska University Hospital, S-413 45 Göteborg, Sweden

Table 1 International classification for surgery of the hand in tetraplegia¹

Group	Motor characteristics	Description
0	No muscle below elbow suitable for transfer	Flexion of elbow and supination
1	Brachioradialis	
2	Extensor carpi radialis longus	Extension of wrist (weak or strong)
3	Extensor carpi radialis brevis	Extension of wrist (strong)
4	Pronator teres	Extension and pronation of wrist
5	Flexor carpi radialis	Flexion of wrist
6	Finger extensors	Extrinsic extension of fingers (partial or complete)
7	Thumb extensor	Extrinsic extension of the thumb
8	Partial digital flexors	Extrinsic flexion of fingers (weak)
9	Lacks only intrinsic	Extrinsic flexion of fingers
X	Exceptions	

The absence or presence of tactile gnosis (2 point discrimination <10 mm) is designated by a prefix O (Ocular) and OCu (oculo-cutaneous) respectively. Adding Tr- and Tr+ respectively indicates the absence or presence of triceps function minimum grade 3. Each arm is classified separately

of the tendon sheaths widely to increase the moment arm at the metacarpo-phalangeal joint and hopefully to obtain better metacarpo-phalangeal joint flexion to provide a platform for the strong thumb pinch. One might consider in such a patient moving the pronator teres out more distal on the radius by attaching it to the flexor carpi radialis to provide some wrist flexion, particularly when the forearm is pronated and the hand wants to open to grasp around an object.

Second comment: F Holst-Nielsen

Classification

The classification is somewhat uncertain, as we do not know if the ECRB is potent. If it is, your case should be classified as OCu:4 in both hands. Triceps minus bilaterally.

Treatment plan

I would prefer to operate on the patient in four stages:

- 1 Posterior deltoid to triceps on the left side.
- 2 Posterior deltoid to triceps on the right side.
- 3 Left hand: Pronator teres to FPL, ECRL (if the power of ECRB is of grade 4 or better) to flexor digitorum profundus.
- 4 Split FPL to EPL for stabilisation of the interphalangeal joint of the thumb or temporary arthrodesis.
- 5 I would keep BR in reserve for later adjustment of the grip. You might need a long extensor (and radial abductor of the thumb): BR to EPL re-routed subcutaneously.

I would prefer to postpone a possible activation of the right hand till we see what the result will be of our efforts performed on the left hand. A totally different pattern of handgrip might be needed in the opposite hand.

Third comment: M Keith

Classification

According to the ASIA classification this patient has C6 level motor function and sensory function, as triceps do not exceed a grade of 3. According to the International Classification he would be group OCu:4 as he lacks FCR at grade 4 and has a grade 4 pronator teres and all proximal muscles as well.

Treatment plan

I recommend further muscle grading of the posterior deltoid and if it has grade 4 strength, although it does not change the classification, it might change our practice and suggest transfer for elbow extension.

The thumb interphalangeal joint flexion posture is most readily balanced by transfer of the radial slip of the FPL to the extensor pollicis longus (EPL) distal to the thumb interphalangeal joint through a radial mid-lateral incision. (Modified from Mohammed, Sinclair and Rothwell³). Eliminating adduction and abduction and extending and pronating the thumb through arthrodesis of the first carpo-metacarpal joint makes the extrinsic thumb muscles more efficient by reducing the required excursion and precisely aligning the thumb to contact the index finger for lateral prehension.

The ECRB can be transferred through the interosseous membrane volar to the deep finger flexors of index long and ring fingers to provide active finger flexion. Although this reduces the moments for wrist extension and increases the moment for wrist flexion, the ECRL remains a strong extensor and learned tenodesis grasp patterns persist. The ECRB inserts on the ulnar side of the axis of the radius, maintaining radial/ulnar deviation balance. Finger balance is set during the tendon weave and allows index flexion before long flexion before ring flexion and does not power the fifth finger.

Active movements of the thumb are desirable but a pathway must be chosen between alternatives. Brachioradialis can be transferred to FPL or EPL.

BR is transferred to FPL The selection of CMC I arthrodesis often permits a very effective EPL tenodesis when re-routed to the second dorsal compartment. The adduction vector of EPL in the third compartment is not needed. Transfer to the first compartment yields ineffective excursion as the insertion point is too close to the axis of wrist flexion/extension. The absence of a wrist flexor, except gravity, makes wrist extensor tenodesis less effective, requires two surgical stages and often stretches out under the constant flexor forces. In the first model, brachioradialis is transferred to FPL.

BR can be transferred to EPL for active thumb extension Elbow extension or stabilisation in extension allows both tenodesis and active thumb extension for object acquisition. Thumb flexion can be provided by tenodesis of FPL to the radius according to Moberg⁵ or as a transfer of FPL side-to-side to the ECRL co-ordinated for lateral prehension.

Exposure of the deltoid and triceps tendon is performed first. The FPL tenodesis is then done; the ECRB to FDP transfer done next so that finger posture and the platform for key grip is set. The CMC I arthrodesis is modelled by temporarily cross-pinning the CMC joint while adjusting the EPL tenodesis. Final posture is set; the joint is resected and cross-pinned.

Transfer of BR or thumb tenodesis are done last as they must be assessed in elbow flexion and extension. The last step is connecting the posterior deltoid transfer. All tendon transfers are evaluated by intra-operative electrical stimulation of the donor muscle using muscle surface electrodes at 20 mA, 0–250 μ s pulse duration, 12–16 Hz.

Tendon transfer for elbow extension can be very strong in C6 patients using the posterior deltoid muscle. Several alternatives for tendon reinforcement, tendon grafting, post-operative immobilisation and rehabilitation exist. In my experience all these procedures can be performed together to reduce cost. The elbow is immobilised in extension and the wrist in neutral position, thumb at rest tension.

We have not recommended a Freehand neuro-prosthesis for patients with this degree of preserved hand function.

Fourth comment: A Rothwell

Classification

On the basis of the muscle chart you supplied I would grade the patient as Ocu:4 bilaterally. I am somewhat surprised at the BR grading on 4 on the right hand side and ECRL as 4 on both sides in view of the grade 4 pronator teres on both sides.

Treatment plan

I would require more information before formulating a definitive treatment plan. Is the flexed thumb position due to a fixed flexion deformity or is it a mobile flexion position and which joint is primarily responsible for this? Secondly, are the fingers fully passively mobile and do they adopt an intrinsic plus or intrinsic minus posture as the wrist is extended from the flexed position. If it is the latter then it is quite possible that the thumb adopts the flexion position during wrist extension because of the absence of the finger platform. To check this it is important to note the posture of the thumb with passive wrist flexion, and then the posture of the thumb when the fingers are held fully flexed into the palm and the wrist is fully extended.

On the other hand, if the fingers adopt an intrinsic plus posture as the wrist goes from flexion to extension then it is very rare for the thumb not to automatically adopt a key pinch position unless there is a flexion contracture usually at the metacarpo-phalangeal joint. Thus based on the above I would need to propose more than one treatment plan.

Deltoid to triceps transfer

I would strongly recommend before hand reconstruction is considered that bilateral posterior deltoid to triceps procedures be carried out which would provide much better overall arm control and of course stabilise the elbow for the BR transfer.

Intrinsic minus posture of fingers

In this situation I would recommend a Zancolli lasso procedure plus or minus release of the metacarpo-phalangeal joint collateral ligaments if there is passive stiffness of the metacarpo-phalangeal joints. One could motor the flexor digitorum superficialis lasso with the pronator teres but the patient should be warned that he could lose some wheelchair manoeuvrability.

On the assumption that this would provide a natural key pinch for the thumb, I would recommend BR transfer to FPL combined with the distal split FPL tenodesis and ECRL transfer to FDP. If on the other hand the thumb still flexed during wrist extension such that a key pinch was not possible then I would fuse the CMC joint in a position to obtain a key pinch.

Thumb opening during wrist flexion could be improved by tenodesis of abductor pollicis longus and EPL using a long length of each tendon taken volar to the CMC joint through the interosseous membrane proximal to pronator quadratus and attached to the insertion of ECRB. This gives excellent opening of the first web during wrist flexion.

The intrinsic plus posture

I would do the same as above but the lasso would not be necessary.

Finger extension

I note on the left side that there is FCR grade 2, which may be sufficient to 'motor' along with gravity, intrinsic and extensor digitorum communis tenodesis. This would require two stage surgery and in my experience patients are not usually prepared to have two phase hand surgery, particularly if they have previously had a deltoid to triceps transfer.

Fifth comment: A Ejeskär*Classification*

Both arms classified as OCu:4, triceps minus.

Treatment plan

The patient wished to have improved hand function and was not interested in having elbow extensor reconstruction, although he certainly would benefit from that. In my opinion it is sometimes difficult to convince patients, like this man, of the benefit of elbow extension, especially as he had 'sufficient' control of his left elbow.

Therefore the following plan was set up:

- 1 Reconstruction of thumb and finger grip in his left hand: (a) Split distal thumb tenodesis; (b) Arthrodesis of the CMC joint of the thumb; (c) Zancolli lasso procedure in all four fingers; (d) Transfer of the BR to FPL; (e) Transfer of the ECRL to FDP II-V; (f) As the thumb on the operating table was a little too much flexed in the metacarpo-phalangeal joint a tenodesis of the very thin extensor pollicis brevis to the dorsum of the first metacarpal was made. That improved the thumb position.

I did not want to make a tenodesis of the EPL as we planned a second step with the left hand involving reconstruction of thumb and finger extension. For this purpose the pronator teres was left intact. Pronator teres is not long enough to be connected to the extensor tendons without an interposed tendon graft. Therefore, when performing the Zancolli lasso procedure the flexor superficialis tendon to the long finger was split in two parts, one for that finger and one for the ring finger leaving the flexor superficialis to the ring finger intact. This can then be used as a tendon graft.

Seven months postoperatively he was satisfied with his left hand and wanted a similar operation of his right hand. He was still not interested in having an elbow extensor, even when he was informed of the advantage of having elbow control when transferring the BR.

In order to give him a right hand different from the left, where he had a CMC I joint arthrodesis, the following procedure was performed:

- 2 Reconstruction of thumb and finger grip in his left hand: (a) Split distal thumb tenodesis; (b) Zancolli

lasso procedure in all four fingers; (c) Transfer of the BR to the FPL; (d) Transfer of the ECRL to the FDP.

If he in the future wants a better opening of the hand it can be accomplished using the pronator teres, either for motoring the FCR creating active wrist flexion and utilising tenodesis of the extensors or for transfer to the extensors.

Discussion*Classification*

All of the authors agreed on the level of the international classification for this patient. However, one could discuss how wrist extension force should be tested in these patients. What is a grade 5 in wrist extension and how should one designate a wrist extension which is strong but can be overcome by manual force? Should we include a numerical measurement of wrist extension force in our evaluations?

This patient had strong wrist extension but he had a very poor spontaneous key grip. In my opinion he can not exercise his wrist extensors maximally and therefore I judged them having strength of grades 4, 5.

It is also apparent that as a surgeon you take a great number of details into consideration when evaluating a patient like this. Many of these details are difficult to describe correctly in words and therefore a personal examination of the patient by the surgeon is mandatory for a proper treatment. A treatment plan for a patient that you have not seen must include points of reservation.

Treatment plan

The proposed solutions depend, not only on each surgeon's experience, but also on local traditions and differences in health and social care systems. In spite of differences on these points the treatment plans are amazingly similar. All authors suggest reconstruction of elbow extensor, but it is a didactic task to teach our patient the value of such an operation.

The split FPL tenodesis is proposed by every author and is definitely a procedure which has come to stay. It is the perfect solution of limiting the flexion of the inter-phalangeal joint of the thumb replacing the temporary arthrodesis suggested by Erik Moberg.

The proposition to use the ECRB to motor the deep finger flexor instead of the ECRL is a challenging idea. The ECRL is not as strong as the ECRB but has greater amplitude. Transfer of the ECRB always leaves the ECRL for wrist extension and thus minimises the risk of transferring the only strong wrist extensor if the ECRB is not fully innervated.

The clinical result in this case illustrates the difficulty in two-stage surgery in an arm. The idea

was to give him the option to have an active finger and thumb extensor after the flexor phase, but so far he has not expressed any wish for that.

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