Dynamic Tenodesis of the Finger Extensors to Improve Hand Function After Brachial Plexus Injury

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Abstract The term “plexic hand” refers to hand and wrist involvement in traumatic brachial plexus injuries and to remaining deficits after nerve surgery has been performed. From January 2000 to March 2008, reconstructive surgery (dynamic tenodesis) was performed on seven patients with C5, 6, 7, and 8 nerve root lesions of the brachial plexus to restore wrist and finger extension. This procedure has been used in seven patients (one female). Two patients with a lesion of the brachial plexus sustained a fracture of the affected limb. Preliminary nerve repair operations were required in four cases. One hundred percent (seven) of the patients had improved function following dynamic tenodesis. The extension angle of the wrist joint on grip was 19° on average. The flexion angle of the wrist joint needed to produce MP joint extension was 24.3° on average. A new dynamic extensor tenodesis technique is proposed. The extensor digitorum communis tendons are looped through dorsal carpal retinaculum ligament and sutured to themselves. Our results demonstrate that the extensor dynamic tenodesis procedure is an effective and simple means of restoring grip function for patients with C5, 6, 7, and 8 nerve root lesions.

Keywords Brachial plexus · Tenodesis · Tendon transfer

Introduction

The functional deficits of the hand in the brachial plexus-injured patient are badly tolerated when the patient notices recovery of the shoulder and elbow function after surgical procedure.

Patients with C5, 6, 7 and 8 nerve root lesions, in which only the T1 root is undamaged, have difficulty in using their hands because they are not able to maintain their wrists in a functional position in order to grasp an object, and they are also unable to open their hands, even though their finger flexor muscles, hand intrinsic muscles, and some wrist flexor muscles are still functioning. In these cases, there are insufficient strong muscles available for transfer [4, 7]. Only tenodesis may restore hand opening in active wrist flexion. This tenodesis is usually performed to the distal radius, but it is possible to fix the extensor digitorum communis (EDC) to the retinaculum extensorum.

Therefore, we proposed a new dynamic extensor tenodesis technique [5, 6]. The extensor digitorum communis tendons are looped through the dorsal carpal retinaculum ligament and sutured to themselves.

Materials and Methods

From January 2000 to March 2008, reconstructive surgery (dynamic tenodesis) was performed on seven patients with C5, 6, 7, and 8 nerve root lesions of the brachial plexus to restore wrist and finger extension. A retrospective study was undertaken to assess the functional outcome in these. Examination was completed in all patients.

This procedure has been used in seven patients (one female). Two patients with a lesion of the brachial plexus sustained fracture of the affected limb. Preliminary nerve

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Table 1 Material.

Case	Age (years)	Affected side	Nerve repair	Fracture of affected limb
1	6	R	Yes	No
2	9	R	No	No
3	44	L	Yes	Clavicle
4	13	R	Yes	No
5	19	L	Yes	Humerus
6	18	L	No	No
7	8	R	No	No

repair operations were required in four cases. The patients' details are presented in Table 1.

On physical examination, all patients complained of difficulty in using their hands because they are not able to maintain their wrists in a functional position in order to grasp an object, and they are also unable to open their hands, even though their finger flexor muscles, hand intrinsic muscles, and some wrist flexor muscles are still functioning.

Full passive range of movement is desirable before any musculotendinous transfer is carried out, and a course of physiotherapy was necessary in most cases.

Evaluation

Active and passive range of movement at the metacarpophalangeal joint (MP) of the fingers, the interphalangeal joint (IP) of the thumb, and the radio-carpal joint were recorded with a goniometer in both the affected and normal limbs. The maximum active span from the thumb pulp to the index was recorded.

The evaluation included extension angle of the wrist joint on grip and the flexion angle of the wrist joint needed to produce metacarpophalangeal joint extension.

Function was graded as good, moderate, weak, or poor (Table 2).

Surgical Technique

Using a pneumatic tourniquet, a long curved incision is made over the dorsum of the distal radius. The tendons of the extensor pollicis longus (EPL), extensor digitorum (ED), extensor indicis (EI), and extensor digiti minimi (EDM) are identified proximally to the dorsal carpal retinaculum ligament (Fig. 1). After dividing tendons of ED, EI, EDM, and, if necessary, EPL at the musculotendinous junctions (Fig. 2), the distal end of each tendon is folded back towards the distal edge of the dorsal carpal retinaculum ligament (Fig. 3) and sutured to itself (Fig. 4a) in such a way that its loop enclosed the dorsal carpal retinaculum ligament under optimal tension (Fig. 4b). Slight tension is recommended to compensate for loss of tension after the operation. A dorsal splint is kept on for 6 weeks with the wrist extended 60°, the MP joints flexed 60°, the IP joints in extension, and the thumb in palmar abduction.

Results

The follow-up period was 21 months on average (range, 6–48). One hundred percent (seven) of the patients had improved function following dynamic tenodesis. One

Table 2 Functional classification.

Function	Description
Good (G)	Good use of hand, effective grasp and release Passive finger extension with less than 20° wrist flexion Passive wrist extension >20° with active finger flexion
Moderate (M)	Moderate grasp and release Passive finger extension with more than 20–40° wrist flexion Passive wrist extension (0–20°) with active finger flexion
Weak (W)	Weak grasp and release Passive finger extension with more than 40° wrist flexion Passive wrist extension <0° with active finger flexion
Poor (P)	Poor grasp and release Impossible passive finger extension even with more than 40° flexion of the wrist Impossible passive wrist extension even with maximal active flexion of the fingers

Figure 1 The tendons of the extensor pollicis longus (EPL), extensor digitorum (ED), extensor indicis (EI), and extensor digiti minimi (EDM) are identified proximally to the dorsal carpal retinaculum ligament (DCRL).

patient complained of loss of function, and this was a transient weakness of the finger flexors following tenodesis, which recovered after 2 weeks (Table 3).

The extension angle of the wrist joint on grip was 19° on average. The flexion angle of the wrist joint needed to produce MP joint extension was 24.3° on average. The range of movement is summarized in Table 4.

Figure 2 Tendons of ED, EI, EDM, and, if necessary, EPL are dividing at the musculotendinous junctions.

Figure 3 The distal end of each tendon is folded back towards the distal edge of the dorsal carpal retinaculum ligament.

The groups are too small for statistical analysis, but the trend suggests that dynamic tenodesis of the finger extensors restore hand function.

Discussion

The results of successful nerve repair are far superior to musculotendinous transfer. However, when nerve repair cannot produce useful motor end plate reinnervation, palliative surgery is a complement to nerve surgery.

Nerve surgery of the upper roots (C5 and C6) often achieved the recovery of a stable shoulder and of elbow flexion but, when C7 is affected, the residual clinical presentation is a dropped hand as in proximal radial palsy.

The term “plexic hand” refers to hand and wrist involvement in traumatic brachial plexus injuries and to remaining deficits after nerve surgery has been performed.

Most patients respond to classical transfers, as described by Jones, Merle d’Aubigne, Scuderi, and Tubiana [2, 3, 9, 10] and admitted by numerous authors with some technical modifications [8].

Wrist extension is the first priority, even if all other muscles are paralyzed; it provides automatic finger flexion by tenodesis effect when the wrist is extended. When there is some active prehension, wrist extension places the hand correctly in front of the object so that it can be seized, and stabilizes prehension. Flexion of the long fingers comes next and allows the most elementary grasp between fingers and palm.

Extension of the metacarpophalangeal joints (extrinsic function) and thumb reposition (that is abduction and retropulsion) follow. They assume the opening of the hand and the adaptation of fingers to its volume, and they are the next step in reconstruction if grasp is present.

Figure 4 **a** The distal end of each tendon is sutured to itself under optimal tension. **b** The dorsal carpal retinaculum ligament is enclosed as a loop by the tendons of *ED*, *EI*, *EDM*, and *EPL*.

Table 3 Hand function after dynamic tenodesis.

Case	Function ^a		Time to educate transfer (weeks)	Loss of function post-operatively	Follow-up (months)
	Before operation	After operation			
1	P	W	2	No	19
2	P	G	3	No	35
3	P	M	1	No	6
4	P	G	6	Transient	48
5	P	M	2	No	10
6	P	G	5	No	27
7	P	M	3	No	3

^a *G* Good, *M* moderate, *W* weak, and *P* Poor

Table 4 Range of movement.

Case	Results	
	Wrist extension on grip (°)	Wrist flexion on finger extension ^a
1	−5	50/−5
2	25	10/−5
3	20	10/−20
4	30	15/10
5	20	10/0
6	40	15/10
7	0	60/0

^a A/B MPJ extends B degrees when the wrist flexes A degrees

In C5, 6, 7, and 8 nerve root lesions, in which only the T1 root is undamaged, restoration of finger active extension is not possible. Only tenodesis may restore hand opening in active wrist flexion. In routine techniques, extensor tendons are fixed on radius.

The concept of dynamic tenodesis is that wrist action is produced by finger movement; the fixed ED, an antagonist to FDP, acts to place the wrist joint in a functional position when grasping an object (Fig. 5). The fixed ED, synergist of the wrist flexors, also functions as a finger extensor as the result of the dynamic tenodesis effect (Fig. 6; Ochiai et al. 1994 [5]). The intrinsic muscles should have MRC power grading of more than 3, because if they are less than 2, the dynamic tenodesis effect for finger extension is absorbed into intrinsic minus position; at least one of the wrist flexors must have manual muscle testing power of more than 2, and the wrist and all finger joints must be supple.

Ochiai et al. [6] proposed a surgical technique dividing tendons of ED, EI, EDM, and, if necessary, EPL at the

Figure 5 ED acts to place the wrist joint in a functional position when grasping an object.

Figure 6 ED, synergist of the wrist flexors, also functions as a finger extensor as the result of the dynamic tenodesis effect.

musculotendinous junctions; the distal ends are pulled into the radial window, out through the other window one by one and sutured to themselves by interlacing under optimal tension.

Restoration of thumb extension is an unsolved problem. In EPL tenodesis, radio-dorsal deviation of the wrist joint is inevitable, and adduction of the thumb occurs during dynamic tenodesis extension, but rerouting EPL beneath the abductor pollicis longus tendon and fixing it to PL end-to-side functions well, stabilizing both the wrist joint and the thumb MP and IP joints (Figs. 3 and 4).

Biomechanical study conducted by Binder et al. [1] suggests that the retinaculum is strong enough to support a surgical tenodesis. A new extensor dynamic tenodesis technique is presented as a result of this study. The ED,

EI, EDM, and EPL tendons are looped through dorsal carpal retinaculum ligament and sutured to themselves.

Our results demonstrate that the extensor dynamic tenodesis procedure is an effective and simple means of restoring grip function for patients with C5, 6, 7, and 8 nerve root lesions.

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