Restoration of finger flexion by pronator teres muscle transfer after brachial plexus injury: a case report

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Introduction

Brachial plexus injuries represent devastating injuries with a poor prognosis. Neurolysis, nerve repair, nerve grafts, nerve transfer, functioning free-muscle transfer, and pedicle muscle transfer are the main surgical procedures for treating these injuries. Good recovery is expected through nerve grafting and nerve transfer in the elbow flexor and shoulder function, but results for forearm muscles and intrinsic muscles of the hand are generally poor [21].

When spontaneous recovery or surgical nerve repair has been unsuccessful, secondary procedures (tendon transfers, arthrodesis, and/or tenodesis) should be considered to obtain partly hand function, similar to that of a tetraplegic hand [7].

Reconstructive surgery of the upper limb in patients with brachial plexus palsy was influenced by the development of hand surgery and by the importance of restoring function to the “plexic hand” (the term plexic hand refers to the remaining deficits of hand and wrist after traumatic brachial plexus injuries) [3, 25].

Case Report

A 37-year-old woman had injured her right brachial plexus in a motorcycle accident 18 months ago. The patient did not undergo early exploration and/or early microsurgical reconstruction.

The patient had a complete assessment of sensibility of the upper limb [17, 19], strength or muscular power based on manual muscle testing [5, 20], Tinel’s sign, Horner’s

syndrome, pain, passive range of motion (shoulder, elbow, wrist, thumb, fingers), finger flexion strength or “grasp” (wrist in 30° of extension), excursion of finger flexion (distance between the pulp of the tip of the finger and the distal palmar crease), and key pinch (the contact point on the index finger where the thumb touched the lateral aspect of the index finger), before and after surgery (Table 1).

Due to the extensive palsy, the thumb and finger flexors and intrinsic muscles were completely paralyzed, but shoulder and elbow range of motion was normal. Although a good protective hand sensation was recovered in the thumb and two radial digits (S3), the limb integration was poor due to poor motor function of the hand (Fig. 1, see Additional file 1).

Neurological function had reached a plateau (14 months after injury). Tendons used for transfer must be grade 4 or better. Electrophysiological studies preoperatively were not requested. The patient was highly motivated as well as psychologically adjusted to cooperate fully with the rehabilitation program and was informed about the use of photo and film material only for academic and scientific purpose.

Surgical Planning

Several procedures have been reported to restore finger flexion. In our patient, only the pronator teres muscle had intact function to be used as a motor for the flexor digitorum profundus (primary procedure). With regard to the restoration of thumb flexion (“key pinch”), brachioradialis was transferred to the flexor pollicis longus (additional procedure).

Details of Surgical Technique

The primary procedure involves the transfer of the pronator teres (PT) to the flexor digitorum profundus (FDP) to restore finger flexion. Suturing all the FDP tendons together at the

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Table 1 Details of the patient and results

A. Preoperative status	
Age in years	37
Gender	F
Cause of injury	Motorcycle accident
Brachial plexus injury side	Right
Initial pattern of paralysis	Total
First visit after injury (months)	14
Pattern of paralysis at first visit after injury	Lower palsy (C7–C8,T1)
Lesion	Supraclavicular
Nerve repair	No
Preoperative MMT (British Medical Research Council Scale)	
Shoulder girdle, biceps brachii, triceps, PT	5
Supinator, BR, ECRL	4
FCR	3
EDC	2
FCU	1
ECRB, ECU, EPL/EPB, FDS, FDP, opponens pollicis, lumbrical, FPL, FPB, AbPB	0
Sensory function	Sensory disturbance was present along the ulnar aspect of the arm, forearm, and hand (ring and little fingers, S0). Good protective hand of the thumb and two radial digits (S3)
Hand sensory recovery grading systems	
S0	No sensory recovery
S1	Recovery of deep cutaneous pain sensibility
S1+	Recovery of superficial pain sensibility
S2	Recovery of pain and some touch sensibility with some over-response
S2+	S2 with over-response
S3	Recovery of pain and some touch sensibility with no over response and with 2PD > 15 mm
S3+	Sensory localization and 2PD recovery between 7 and 15 mm
S4	Complete recovery with 2PD between 2 and 6 mm
Tinel's sign over the brachial plexus at the scalene muscles or supraclavicular fossa	Positive
Horner's syndrome	Present
Neuropathic pain	Present
Passive range of motion of the shoulder, elbow, wrist, thumb, and fingers	No restriction
Finger flexion strength	0
Excursion of finger flexion (cm)	No present
Key pinch	No present
B. Results	
Follow-up (months)	8
Finger flexion strength (transfer PT to FDP)	4
Excursion of finger flexion (cm)	Index finger 1.8, long finger 1.6, ring finger 1.5, and small finger 1.4
Key pinch (transfer BR to FPL)	Thumb contact the lateral aspect of the index finger (middle phalanx)

S4 excellent, S3+ very good, S3 good, S2-2+ fair, S0-1 poor, PT pronator teres, BR brachioradialis, ECRL extensor carpi radialis longus, ECRB extensor carpi radialis brevis, ECU extensor carpi ulnaris, FCR flexor carpi radialis, FCU flexor carpi ulnaris, EDC extensor digitorum communis, EPL/EPB extensor pollicis longus/brevis, FDS flexor digitorum superficialis, FDP flexor digitorum profundus, FPL flexor pollicis longus, FPB flexor pollicis brevis, AbPB abductor pollicis brevis, MMT manual muscle test

level of their musculotendinous junction is useful to adjust their relative tensions so that they will reproduce the cascade of finger flexion.

Distally, the PT tendon is released from its insertion on the radius with a long strip of periosteum to ensure a strong tendon juncture just distal to the musculotendinous junction

Fig. 1 Preoperative flail hand

of the FDP tendons (in our patient, a 10 cm of periosteum strip was obtained) [7]. If PT lengthened with a strip of periosteum from the radius is too short to be attached securely to the FDP tendons, a tendon graft (the APL tendon or a short strip of free tendon graft taken from the extensor carpi radialis longus (ECRL)) is needed to reinforce the transfer [11, 24].

Because the PT is inserted proximally on the medial epicondyle of the humerus, the muscle–tendon unit must be freed up proximally to divide adhesions to improve subsequent excursion. The ulnar head of PT (PTu) is released or excised before transfer to obtain larger excursion [1].

Postoperatively, the arm is immobilized with the wrist in 30° of flexion, the elbow in 90° of flexion, and the forearm in neutral rotation. Protected active motion began 4 weeks after operation. Functional grasp exercises and functional electrical stimulation began 4 weeks after operation. The patient was evaluated at regular intervals and had final assessments 8 months after surgery.

Results

The accurate evaluation of function of hands affected by brachial plexus palsy is very difficult. Because of this difficulty, it was decided not to compare the functional result of surgery in the hand operated on with functions in the normal hand or with function in another hand similarly affected with brachial plexus palsy, but to compare function after operation with that present before operation and after tendon transfer (Table 1).

The postoperative strength of finger flexion (grasp) was M4. Finger and thumb extension was produced as the result of the tenodesis effect when the wrist is flexed. As a result of this gain, when the fingers were in active flexion, the distance from the pulp of the tip of the finger to the distal palmar crease was 1.8 cm for the index finger, 1.6 cm for the long finger, 1.5 cm for the ring finger, and 1.4 cm for the small finger.

The patient obtained a functional pattern of global finger flexion, as documented in Fig. 2. Obviously, the reanimated hand remained a “helping hand,” but a real grasp was now possible (Fig. 2, see Additional file 2).

After the tendon transfer, the key pinch was at the middle part of the middle phalanx with the wrist at 30° of extension. Although active extension of the elbow was not a prerequisite for a good result, the ability to stabilize the elbow (when the triceps is intact) resulted in increased pinch strength.

Discussion

Paralysis occurring with injury to the brachial plexus produces severe disability. When spontaneous recovery or surgical nerve repair has been unsuccessful [21], hand splints or secondary procedures (tendon transfers, arthrodesis, and/or tenodesis) should be considered to improve some function which might increase the patient’s independence.

The first attempts at producing some gripping function of the hand took place in Europe [16] with the construction of flexor hinge splints and continuing interest in the use of hand splints in the years that followed resulted in the Rancho Splint developed by Nickel et al. [22]

In the 1950s, the development of surgical techniques such as static flexor tenodesis provided the basic functions of grasp and pinch for patients who lacked sufficient muscle motors for conventional transfers but in whom active wrist dorsiflexion was present [12, 23, 26, 29].

Restorative procedures for upper extremity functions after brachial plexus injuries are principally determined according to their pathological conditions. Tendons used for transfer to restore hand function must be grade 4 or better and the automatic synergist mechanisms should be considered [30–32].

In residual paralysis involving the C7–C8 and T1 nerve roots, the recovery of finger flexion is always incomplete or absent. Shoulder and elbow range of motion is normal. The thumb and finger flexors and intrinsic muscles are completely paralyzed. Wrist extension is weak, and radial deviation occurred because the extensor carpi radialis longus is functioning, and the extensor carpi radialis brevis and the

Fig. 2 Postoperative function

extensor carpi ulnaris were paralyzed. Tinel's sign over the brachial plexus is considered as a diminution of the threshold of nerve fibers to mechanical stimulus [10].

In long-standing palsy (more than 12 months) and neurological function which had reached a plateau, electrophysiological studies did not contribute, in any way, to identifying indications for surgery or to surgical planning. Consequently, we no longer request electrophysiological studies preoperatively.

The functional outcome after the reconstruction of lower type paralysis is proportional to the number of transferable muscles in the forearm.

To restore voluntary and useful finger flexion, the ECRL, brachioradialis (BR), flexor carpi radialis (FCR), or PT can be used as motors for the FDP tendons if they have intact function. The ECRL is the best motor for transfer to the FDP and flexor pollicis longus (FPL), because it is synergic and the tenodesis effect that is related to active wrist extension via the remaining extensor carpi radialis brevis (ECRB) adds approximately 2 cm of tendon excursion.

Voluntary wrist extension is the key to good grasp with or without surgery. Adding voluntary finger and thumb flexion makes a more effective grasp. When active wrist extension is present, it must not be weakened. Therefore, the extensor carpi radialis longus can only be used in patients where active extension is supplied by both the extensor carpi radialis longus and the extensor carpi radialis brevis. In our patient where active extension of the wrist depends only on the extensor carpi radialis longus, this muscle was not suitable for transfer [24].

Brachioradialis transfer into the flexor digitorum profundus results in a weak to moderate active control of the finger flexors ("helper hand") [18]. Numerous studies have shown that the BR is a suitable muscle to transfer to the tendon of the FPL to reestablish lateral pinch strength [1–6, 8, 9, 14, 20, 21, 27]. Before surgery, the BR must be able to sustain moderate resistance (muscle grade 4) to expect functional levels of pinch force after surgery [14].

The BR normally does not contract during lateral pinch or closing the hand [6, 13, 28] but can be reeducated to become activated during pinch tasks and provide pinch force through the tendon of the FPL [28]; therefore, we decided transfer the BR to FPL to restore key pinch.

The FCR was not suitable for tendon transfer (grade 3) (Table 1). The pronator teres is used as a donor muscle in many tendon transfer surgeries. In particular, the pronator teres often is transferred to the extensor carpi radialis brevis to restore wrist extension in patients with tetraplegia or radial nerve palsy.

Gansel et al. [7] reported transfer of the pronator teres tendon to the tendons of the flexor digitorum profundus in selected tetraplegic patients. Additionally, pronator teres to extensor pollicis longus transfer also has been used to restore thumb extension in patients with similar injuries [2, 24].

Lieber et al. [15] showed that the pronator teres with short, highly pennated fibers had the highest physiologic cross-sectional area of all the forearm muscles. The pronator teres was found to have a force potential similar to the ECRB and a low difference index, indicating architectural similarity.

From the hand surgeon's point of view, it is reasonable to release or excise the PTu before transfer based on the fact that the PTu is likely to restrict excursion after transfer and provides only a small (10 %) portion of the total force produced by the PT. These data suggest that releasing the ulnar head of the PT before transfer may result in larger excursions of this important motor in tendon transfer surgery [1].

In our patient, only the pronator teres (grade 5) muscle was suitable to be used as a motor for the FDP tendons to restore finger flexion. The pronator teres transfer is a good and reliable method for restoring finger flexion in a paralyzed hand after brachial plexus palsy when others options are not available (extensor carpi radialis longus, brachioradialis, or flexor carpi radialis). Restoring active finger flexion is useful for finger flexion grasp and also serves to place the fingers in a more suitable flexed position for lateral pinch between the thumb and the lateral aspect of the index finger.

Conflict of interest The author declares that he has no conflicts of interest, commercial associations, or intent of financial gain regarding this research.

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