Correction of wrist flexion deformity in spastic hemiplegic cerebral palsy with flexor carpi ulnaris transfer

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Objective
The aim of this study was to present the results of correction of wrist flexion deformity in a series of young children with hemiplegic cerebral palsy (CP) and impaired hand function.

Patients and methods
The study included 28 children (15 boys and 13 girls) with pure spastic hemiplegic CP and wrist flexion deformity. The mean age of the children was 7.3 years. They were subjected to transfer of the flexor carpi ulnaris to extensor carpi radialis brevis for the treatment of their wrist flexion deformity.

Results
All patients' parents reported cosmetic improvement and 64.2% of them reported functional improvement. The success rate evidenced by an improvement in the functional grade was 42.8% at 6 months and 75% after 2 years of follow-up. Functional improvement was inversely proportional to the grade of spasticity and positively associated with the cognitive level.

Conclusion
Flexor carpi ulnaris to extensor carpi radialis brevis transfer seems to be a good surgical option for the management of children with spastic CP with impaired hand function, with a 75% success rate after 2 years of follow-up, with satisfactory cosmetic results.

Keywords:
cerebral palsy, spastic hemiplegic, wrist flexion deformity

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Introduction

Cerebral palsy (CP) is a collective term used to describe a large group of children with a variety of musculoskeletal impairments, resulting from a static lesion or injury to the immature brain. In addition to motor disorders, children with CP may have cognitive impairment; learning difficulties; epilepsy; and respiratory, visual, gastrointestinal, and auditory problems. The most common form of CP is spastic CP, which is defined as a velocity-dependent increase in muscle tone and hyper-reflexia [1–3].

Spasticity leads to shortening of musculotendinous units, which in turn causes fixed contractures and can eventually lead to torsional abnormalities of long bones, joint instability, deformity, and degenerative arthritis [4–6].

In these children, the primary concern is always the inability to stand and walk; the upper limb is often ignored [7]. In patients with spastic CP, the typical upper limb deformities in CP include internal rotation and adduction of the shoulder caused by spasticity and contracture of pectoralis major and subscapularis muscles, elbow flexion, and forearm pronation [2]. This deformed posture contributes to the impairment in hand function [8].

Hand function is essential to activities of daily living for everyone, including individuals with CP. Impaired hand function is the primary problem in at least 50% of children with hemiplegic CP [9]. Individuals with hand dysfunction experience difficulties in self-care as well as educational, recreational, and fitness activities [10]. Difficulty in these activities may preclude participation with peers and may therefore adversely affect an individual's quality of life [11].

Many attempts to correct upper limb deformity have been described including denervation, myotomy, tenotomy, tendon lengthening, tendon transfer, tenodesis, capsulotomy, excisional arthroplasty, and arthrodesis [12,13]. The release of tendons or muscles combined with tendon transfer is always preferable [14].

Flexion deformity of the wrist decreases the grip power and impairs the grasp pattern. Transfer of flexor carpi ulnaris (FCU) as described by Green is an excellent procedure for improving extension of the wrist, but its effect on supination when accompanied by a pre-existing pronation contracture is small. When there are severe contractures of the wrist and fingers, tendon transfers alone are not successful [15]. The release of the flexor pronator origin is effective for the correction of severe flexion contracture of the wrist and fingers, but does not restore the ability to supinate the forearm actively or to extend the wrist and fingers [16].

The aim of this study is to present the results of correction of wrist flexion deformity in a series of young children with CP with impaired hand function as a first step in the management of impaired function of the upper limb.

Patients and methods

All patients included in this study had pure spastic hemiplegic CP with flexion deformity of the wrist. Patients with mixed patterns of affection and those who had previously undergone surgery or were in need of complementary surgery of the hand other than FCU transfer were excluded. The group studied ($n = 28$) included 15 boys and 13 girls, mean age 7.3 years (range 5–14 years).

Preoperative evaluation

During assessment of history, we focused on possible obstetric risk factors and development of milestones. Evaluation of cerebral function included intellectuality, cooperation, concentration, attention, and progress in school in addition to volition of the child toward the limb involved: whether he/she is trying to use the limb or is completely ignoring it. Previous modalities of nonsurgical treatment were recorded.

Physical examination

Each child was observed to assess gait, cooperation with orders, and communication with care givers. Spasticity was graded according to the Modified Ashworth Score (Table 1) [17].

Examination of the upper limbs

The overall position of the limb was observed and each joint was assessed in terms of position at rest, and passive and active range of motion (ROM). The discrepancy between active and passive ROM was assessed to elucidate its cause.

Examination of wrist and fingers

The position at rest and passive and active ROM were assessed. Active digital extension with the wrist held passively in both flexion and extension was then assessed, and finally, the passive finger extension to determine long flexor tightness (using the Volkman's angle) was assessed. The thumb was examined and classified according to the Mital and Sakellarides [16] classification (Table 2). Intrinsics were examined for tightness and the presence or absence of swan neck deformity of the fingers.

Table 1 Modified Ashworth Score [17]

Grade 0	No increase in muscle tone
Grade 1	Slight increase in muscle tone, manifested by a catch and release, or by minimal resistance at the end of the ROM when the affected part(s) had moved into flexion or extension
Grade 1+	Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the rest (less than half) of the ROM
Grade 2	More marked increase in muscle tone through most of the ROM, but affected part(s) easily moved
Grade 3	Affected part(s) rigid in flexion or extension
Grade 4	Affected joint is stiff and cannot be moved

ROM, range of motion.

Assessment of hand function

Hand function was graded according to two systems: the modified Green and Banks [18] system (Table 3) and the House *et al.* [19] grading system (Table 4).

The chief complaint was cosmetic disfigurement in four patients, functional disability in 15 patients, and both in nine patients. Obstetric history showed that 12 children were born with a low birth weight (<1500 g); eight of them had been incubated. According to cognition and volition, patients were classified into three categories: A: ($n = 11$) highly cooperative, obeying orders, and doing quite well in school; B: ($n = 10$) short attention span, moderately cooperative, and doing rather poor in school; and C: ($n = 7$) uncooperative, neglecting their affected limb, and three of them dropped out of school. The degree of spasticity is shown in Table 5.

Upper limb examination

Four upper limbs had pronation deformity of the forearm. Five upper limbs had long flexor tightness that did not

Table 2 Mital and Sakellarides [16] classification

Deformity	Description
Type I	Paresis of the extensor pollicis longus, with or without instability of the MCP joint
Type II	Spasticity or contracture of the adductor pollicis
Type III	Paresis of the APL
Type IV	Overactivity of the FPL

APL, adductor pollicis longus; FPL, flexor pollicis longus; MCP, meta carpo phalangeal.

Table 3 Green and Banks [18] system

Poor	Use of the hand only as a paperweight, poor or absent grasp and release, and poor control
Fair	Use of the hand as a helping hand, but no effectual use of the hand in dressing, eating, and general activities. Moderate grasp and release. Fair control
Good	Use of the hand as an aid in dressing, eating, and general activities. Effectual grasp and release. Excellent control
Excellent	Good use of the hand in dressing and eating and other daily life activities. Effectual grasp and release. Excellent control

Table 4 House *et al.* [19] grading system

Grade	Activity level
0	Does not use
1	Use as stabilizing weight only
2	Can hold onto objects placed into the hand
3	Can hold object and stabilize for use by the other hand
4	Can actively grasp an object and stabilize it weakly
5	Can actively grasp an object and stabilize it well
6	Can actively grasp object, stabilize it well, and manipulate it against the other hand
7	Can perform bimanual activities easily, occasionally use the hand spontaneously
8	Uses the hand completely independently without reference to the other hand

Table 5 Degree of spasticity in the studied group (*n*=28)

Grade	*n* (%)
Grade 1	11 (39.3%)
Grade 1+	6 (21.4%)
Grade 2	4 (14.3%)
Grade 3	3 (10.7%)
Grade 4	4 (14.3%)

necessitate a surgical intervention; three of them had mild flexor digitorum superficialis and flexor policis longus tightness. Wrist extension weakness with grasp was observed in 24 patients; the remaining four patients had fixed wrist flexion deformity (10–30°). All patients had active finger extension. Two upper limbs had type I deformity of the thumb [16].

Operative management

All patients were subjected to FCU to extensor carpi radialis brevis (ECRB) transfer to restore active wrist extension. The release of the FCU from its origin was satisfactory to release the wrists in patients with fixed wrist flexion deformity.

Operative technique [18]

Incision was anterior longitudinal along the line of the FCU tendon, extending from the flexor crease of the wrist to the middle third of the forearm proximally. The insertion of the FCU on the pisiform bone was exposed. The tendon was detached from the bone and dissected proximally. The attachment from the muscle to the ulna was freed by a sharp extra periosteal dissection. The ulnar nerve was seen in a sheath dorsal and radial to the tendon. A nylon suture was then fixed into the distal end of the tendon and pulled gently to outline the course of the muscle proximally. The lateral margin of the muscle was defined and an incision through the deep fascia was made to expose this margin and the deep surface of the muscle. Once the muscle belly had been defined, its origin was dissected on the deep surface of the deep fascia and from the ulna distally. The muscle was freed further to pass straight from its origin across the border of the ulna to the dorsal aspect of the wrist. Branches from the ulnar nerve to the muscle were located and preserved. At a suitable level at the medial margin of the ulna, an intermuscular septum separating the volar and dorsal compartments of the forearm was excised for 4–5 cm to expose the dorsal compartment. Then, a second transverse incision 3 cm long was made on the dorsum of the forearm parallel to the transverse skin crease on the dorsum of the wrist to expose the ECRB tendon. The free end of the FCU was delivered into the second incision. A buttonhole was made in the chosen tendon to pass the FCU tendon through it. Then, the FCU tendon was sutured there under tension with the forearm in full supination and the wrist in at least 45° extension. The wounds were closed and a cast from the tips of the fingers to the axilla was applied holding the wrist in extension, the forearm in supination, the fingers in almost complete extension, and the thumb in abduction and opposition.

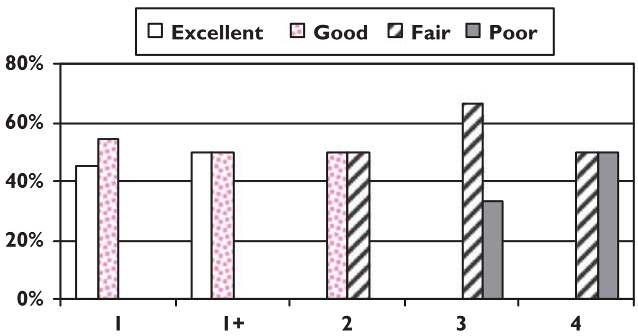
Table 6 Results of treatment according to the Green and Banks [18] grading system

		Postoperative *n* (%)	
Grade	Preoperative *n* (%)	6 months	2 years
Excellent	1 (3.6%)	3 (10.7%)	11 (39.3%)
Good	3 (10.7%)	9 (32.1%)	10 (35.7%)
Fair	16 (57.1%)	10 (35.7%)	4 (14.3%)
Poor	8 (28.6%)	6 (21.4%)	3 (10.7%)

Table 7 Results of treatment according to the House *et al.* [19] grading system

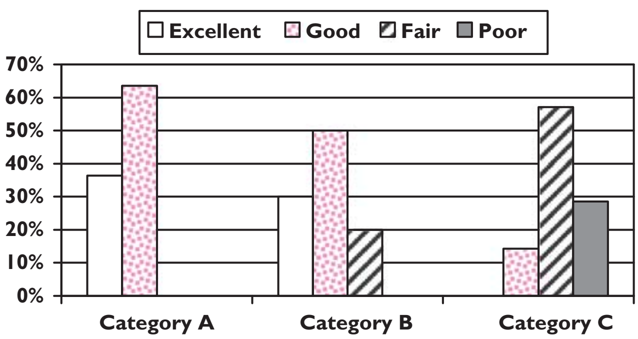
		Postoperative *n* (%)	
Grade	Preoperative *n* (%)	6 months	2 years
0	1 (3.6%)	0	0
1	2 (7.1%)	3 (10.7%)	2 (7.1%)
2	3 (10.7%)	3 (10.7%)	1 (3.6%)
3	10 (35.7%)	5 (17.9%)	2 (7.1%)
4	7 (25.0%)	6 (21.4%)	4 (14.3%)
5	3 (10.7%)	3 (10.7%)	7 (25.0%)
6	2 (7.1%)	4 (14.3%)	4 (14.3%)
7	0	4 (14.3%)	5 (17.9%)
8	0	1 (3.6%)	3 (10.7%)

Figure 1



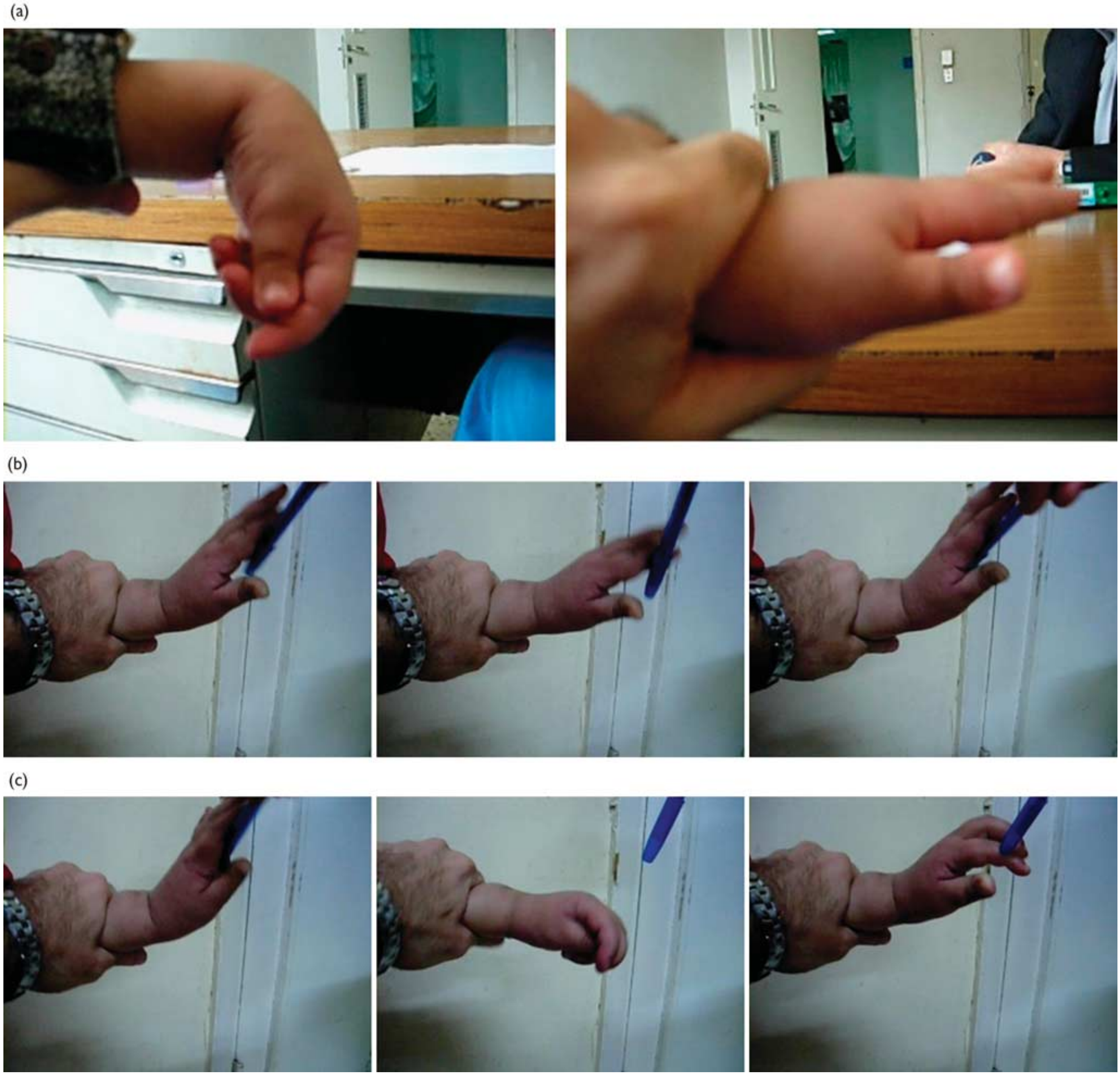
Relationship between spasticity and functional improvement.

Figure 2



Relationship between cognition categories and functional improvement.

Figure 3



Six-year-old boy with left spastic hemiplegia. (a) Preoperative appearance and function. (b, c) Postoperative appearance and function.

Postoperative rehabilitation and evaluation

Hospital stay was only for 1–2 days. The cast was removed after 6 weeks. Night removable splints were used until maturity to prevent the potential recurrence of deformities. Patients and their families were instructed to follow an exercise program with active reach, grasp, and release.

Postoperative physiotherapy program

(1) Full passive stretch of all upper limb joints.
(2) Passive stretching of all flexible joint deformities.
(3) Exercising of the weak muscles.
(4) The patients were especially encouraged to use the affected limb, to engage in bimanual usage, and to enhance their limb usage.

Postoperative evaluation

Patients were functionally evaluated twice, at 6 months and 2 years, using the modified Green and Banks system [18] and the House *et al.* [19] classification. Excellent and good grades were considered to represent successful treatment.

Statistical methods

Data were analyzed using the SPSS statistical package for Windows, version 15 (SPSS Inc., Chicago, Illinois, USA). Qualitative data were expressed as frequency and percentage. The χ^2-test (Fisher's exact test) was used to examine the relationship between qualitative variables. Comparison between preoperative and postoperative frequencies was carried out using McNemar's sign test as appropriate. A *P*-value less than 0.05 was considered significant.

Figure 4

A 5.5-year-old girl with left spastic hemiplegia. (a) Preoperative appearance and function. (b) Postoperative appearance and function.

Results

All patients and their families were satisfied in terms of cosmetic improvement. In terms of functional improvement, 18 children and/or their families (64.2%) expressed satisfaction.

Evaluation of hand function

Preoperatively, 24 children were graded fair or poor. Six months after treatment, 12 patients (42.8%) were considered to have undergone successful treatment (graded excellent or good). The success rate increased to 75% (21 of 28 cases) after 2 years of follow-up according to the Green and Banks grading system [18] (Table 6). According to the House *et al.* [19] grading system, grades 5–8 were considered to represent successful treatment. Thus, the success rate was 42.8% (12 of 28 patients) after 6 months and 67.9% (19 of 28 patients) after 2 years (Table 7). Functional grade showed a statistically significant improvement after 6 months

($P = 0.038$) and 2 years ($P < 0.001$) of surgery (Figs 1 and 2).

The relationship between functional improvement and spasticity showed that grade 1 and 1+ spasticity were associated with a more successful outcome ($P < 0.001$) (Fig. 3).

The relationship between functional improvement and cognition categories showed that category A was associated with a more successful outcome ($P < 0.001$; (Fig. 4).

Discussion

The objectives of surgery were to improve function, cosmoses, and hygiene. In the current study, we achieved active wrist extension with FCU to ECRB transfer. The main goal, therefore, was functional improvement of the hand as the shoulder and elbow deformities in this selected group were minimal. Children were encouraged to participate in postoperative rehabilitation to ensure adequate muscle strength and good voluntary motor control. Sufficient intellectual capacity and cognitive function played an important role in the improvement of fine hand function in grasping and controlled release.

According to the functional grading systems [18,19], hand management in the current study showed a statistically significant improvement after a follow-up of 6 months ($P = 0.038$) and 2 years ($P < 0.001$). The success rate was 42.8% (12 of 28 patients) after 6 months and 67.9% (19 of 28 patients) after 2 years. Success was inversely proportional to the degree of spasticity and cognition impairment.

FCU tendon transfer to either the extensor carpi radialis longus or the ECRB has become a standard procedure to improve function in patients with CP. Wolf *et al.* [20] carried out a retrospective study on 16 children who had undergone this procedure and were followed up to an average of 4 years. They reported improved resting position. Subjectively, 15 of 16 parents were satisfied.

In a prospective study including 27 upper extremities, significant improvement in arm dysfunction was reported as early as 6 months postoperatively. The improvement remained essentially unchanged up to 4.5 years of follow-up [21]. Similar results have been reported by Beach *et al.* [22], with 88% cosmetic improvement and 79% functional improvement. They reported that patients aged older than 12 years showed less functional improvement [22].

Recently, Patterson *et al.* [23] reported that FCU to ECRB tendon transfer remains a viable option to treat the wrist flexion deformity encountered in patients with CP. They found almost 50% incidence of postoperative deformity, commonly an extension deformity, in 25 patients. They believe that these deformities develop when the patient enters a growth spurt and the transferred muscle–tendon unit does not lengthen at the same rate as the upper extremity involved. We did not encounter such an incidence as our patients had not yet reached maturity.

Van Heest *et al.* [24] used electromyographic video analysis in spastic hemiplegic children treated with FCU to ECRB transfer. The pattern of firing of FCU in a grasp and release functional activity was tested. The authors reported that, most often, the FCU does not change phase when transferred from a position of wrist flexion to wrist extension. Most commonly, FCU are activated during grasp and relaxed during release [24].

This procedure does not affect supination of the forearm and can even be beneficial for the correction of pronation deformity. A laboratory study examined the forearm supination effect of FCU transfer to ECRB and to extensor carpi radialis brevis (ECRL) in a cadaveric model. This study showed that transfer of the FCU into either the ECRB or the ECRL provided similar resultant supination and that freeing the distal two-thirds of the FCU ulnar origin provided significantly more supination than freeing only the distal one-third. For the hand surgeon treating wrist flexion in combination with a forearm pronation deformity, transfer of the FCU into the ECRB and/or the ECRL can be used to concomitantly provide wrist extension and forearm supination [25], although it is very difficult to assess active supination in such patients.

Conclusion

FCU to ECRB transfer is a good surgical option for the management of children with spastic CP with impaired hand function. It achieved a success rate close to 75% after 2 years, with satisfactory cosmetic results.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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