A new technique of flexor carpi ulnaris transfer in multilevel surgery for upper extremity deformities in spastic cerebral palsy

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ABSTRACT

Aim To assess treatment outcomes of cerebral palsy (CP) patients who underwent upper limb surgical treatment including new technique of flexor carpi ulnaris (FCU) transfer.

Methods The study included an outcome of orthopaedic surgeries in 30 upper limbs of 25 CP patients aged 10 to 24 years (mean age of 15.1 years). In addition to standard orthopaedic assessment, we used the integral scales of the Gross Motor Function Classification System (GMFCS) and Manual Ability Classification System (MACS). Functional disorders of the upper limb were also evaluated with classifications of Van Heest, House, Gshwind and Tonkin.

Results A total of 30 surgical interventions were performed. In seven patients with hemiparesis, surgical treatment was accompanied by simultaneous intervention on the lower limb. Improvement of the functional capabilities and cosmetic appearance was noted in all cases in a follow-up over 12 months, as evidenced by an improvement in the functional class according to Van Heest classification.

Conclusion A new technique of FCU transfer to the radius showed to be an effective method to address pronation contracture of the forearm joints and can be used in combination with other elements of surgical intervention for elbow and thumb contractures. The FCU rerouting and transfer to distal radius is a good option in the absence of active supination. Distal release of FCU weakening flexion forces with a simultaneous procedure restoring active wrist extension provides satisfactory outcomes in the treatment of associated flexed wrist contracture.

Key words: cerebral palsy, *flexor carpi ulnaris* transfer, pronation contracture

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INTRODUCTION

Cerebral palsy (CP) is a neurological, non-progressive disorder that affects the central nervous system. It is a heterogenic group of clinical syndromes describing impaired motion and posture, characterized by pathological muscular tone, impaired control of movements and body position (1,2).

Classically, CP patients with upper limb spasticity present with a flexed wrist, thumb-in-palm, and forearm pronation deformity (3,4). Depending on the severity, the wrist and hand contracture may produce a hygienic and cosmetic problems, and/or functional disability (4-6). Contractures of the upper limbs, dislocated joints, deformities in patients with CP developing due to muscle retraction and causing serious functional limitations are known to be indications to operative orthopaedic treatment (3-6). Disturbed physical appearance is also an important consideration for surgery. The wrist and hand contracture make grasp, pinch, and release activities difficult or even to impossible to perform and maintain (4, 7-13).

Pronation contracture is observed in 48-50% of patients with upper limb injuries (4) with prevalence up to 86% in hemiparetic CP associated with severely impaired functional activity in the affected side (7-10). The wrist flexion contracture determines the appearance of the limb and significantly limits the implementation of various types of grip (6,8). The thumb-in-palm deformities represent one more special condition requiring surgical correction (7,9,14).

A multi-level surgery in a single procedure is preferable to many small procedures (15,16). The aim of this study was to investigate a correction of forearm pronation, wrist flexion and thumb-in-palm deformities performed throughout single-event procedure in CP patients and to assess the outcomes of operative procedures in their various combination on upper limbs in CP patients where new technique of *flexor carpi ulnaris* was applied.

PATIENTS AND METHODS

The study included outcome of orthopaedic surgeries in upper limbs of 25 CP patients aged 10 to 24 years (mean age of 15.1 years). A total of 30 operative interventions were performed in the period 2013-2019 in the National Ilizarov Medical Centre for Traumatology and Orthopaedics, Kurgan, Russian Federation. Limited articular function and deformities of upper limb of different severity was the main complaint of all patients. Patients were divided into two groups after physical examination: group 1 with spastic diplegia (n=9) and group 2 with hemiparesis (n=16).

In addition to standard orthopaedic assessment of the outcomes, the integral scales of the Gross Motor Function Classification System (GMFCS) (2) and the Manual Ability Classification System for children with Cerebral Palsy MACS were used (6). For a differentiated evaluation of various motor and functional disorders of the upper limb, the classifications of Van Heest for hand function disorders (17), House classification (4), Gshwind and Tonkin classification were used (10).

The House classification (4) was used to assess position and function of the thumb. This classification grouped patients depending on the type and severity of contracture of the first metacarpal-phalangeal and interphalangeal joints. Gshwind and Tonkin classification (10) was used to assess the severity of pronation contracture of the forearm that was classified into four types of contracture: type 1 included possibility to supinate actively beyond neutral, type 2 included possibility to supinate actively to get neutral position or less, type 3 showed no active supination with the possibility of passive forearm supination to be achieved, and type 4 had no active and passive supination.

This research was approved by the Ilizarov Centre Review Board. The study complies with the Declaration of Helsinki statement on the medical protocol and ethics. Representatives of all patients enrolled in the study provided an oral and written informed consent.

Methods

Surgical technique. Various combinations of surgical elements were used during interventions depending on the presence and severity of forearm orthopaedic disorders. As a retrospective cohort, there were no criteria for the choice of surgery, and the decision was made by each surgeon based on his experience: procedures involving the pronator teres muscle; release at distal ends; transposition of the pronator teres to the extensor's carpi radialis; myotomy of the pronator quadratus muscle; radial (rotational) osteotomy; adductor and/or first dorsal interosseous releases; first web Z-plasty; flexor pollicis longus lengthenings; fractional or Z-lengthening of flexors digitorum; *shortening of the extensor pollicis longus and the extensor pollicis brevis tendons; f*lexor carpi ulnaris (FCU) rerouting and transposition to distal radius.

The surgical techniques for the first six groups of procedures were standard ones (5, 7-12). But, the last type of the procedure was specific (Figures 1,2). *M. flexor carpi ulnaris* was exposed using medial approach in the distal and middle third of the forearm and sutured distally at the site of attachment with tenotomy and mobilization produced with two thirds. Radius was exposed subperiosteally using S-shaped approach in the lower third of the forearm. The tendons of the *abductor pollicis longus*, *extensor pollicis brevis* muscles and the distal tendon of the brachioradialis muscle being adjacent to the radius periosteum at the level where they were exposed. The canal in the radius was produced in the radial shaft distal third or in the distal metadiaphysis. Trajectory of the canal was arranged in a blunt manner in oblique descending way under the posterior forearm muscles to drag the *M. flexor carpi ulnaris* tendon. Ulnar flexor threads and a portion of the tendon run through the canal, were sutured back to the tendon, and to the tendon of the brachioradialis muscle and periosteum applying interrupted sutures. The forearm and the hand were secured in a maximally supinated position while suturing. It should be emphasized that the transfer of the FCU to the distal radius provides a supination moment arm, which is greatest if the FCU is released two-thirds of the length of the forearm as it wraps around the ulna onto the dorsum of the wrist.

One of the variations of the above-mentioned manipulation implies attachment the tendon to the radius using an anchor. Torsion of the forearm bones and severely rigid contractures of the joints were found in the upper limbs in two patients with no active and passive supination. Excessive pronation value was of more than 50° in both patients. A derotation radius osteotomy (Figure 3) has been done to correct tortional deformity in both patients. A locked titanium plate was used for osteosynthesis.

The Z-shaped skin plasty of the first interdigital space was performed in combination with teno-

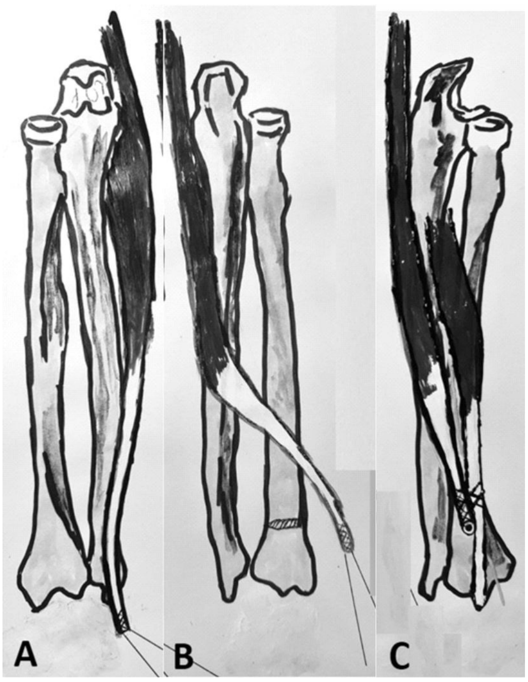

Figure 1. Schema of the surgical technique. A) FCU exposed, distally sutured and mobilized by tenotomy (front view); B) FCU tendon run through the oblique descending canal towards the distal radius (back view); C) FCU sutured to the anchor and distal tendon of the brachioradialis (lateral view) (Chibirov G, 2020)

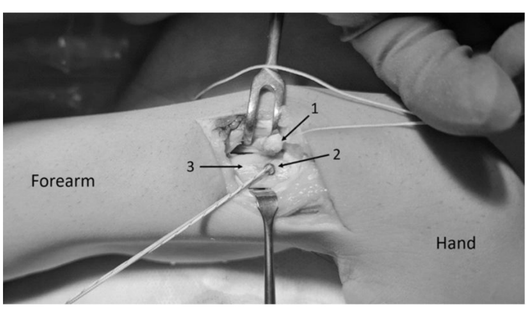

Figure 2. Photo of the approach and FCU tendon attachment, arrows point out: 1 – distal portion of FCU tendon; 2 – anchor inserted into distal radius; 3 – distal radius (Popkov D, 2020)

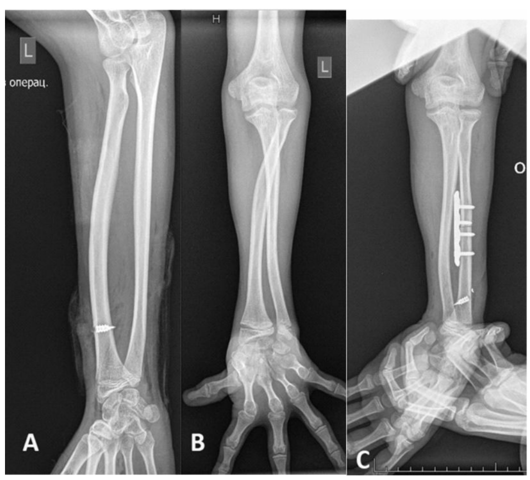

Figure 3. Radiographs of forearm. A) Radius with inserted anchor; B) forearm before surgery; C) anchor into radius, derotation osteotomy, osteosynthesis with locked plate (Chibirov G, 2018)

tomy of the transverse portion of the adduction pollicis muscle, aponeurotomy of the *flexor pollicis longus muscle to address impaired function of the thumb* if indicated.

Statistical analysis

The statistical values were described as the mean and standard deviation.

RESULTS

In the group 1 (spastic diplegia) four patients were classified as GMFCS level II, four as GMFCS level III and one patient as GMFCS level IV; three patients were classified as MACS level II, four as MACS level III, and two as MACS level IV. In the group 2 (spastic hemiparesis) 11 patients were classified as GMFCS level II, five as GMFCS level III; nine were classified as MACS level II, four as MACS level III and three as MACS level IV.

The House classification evaluated the use of patients' hand as type 1 (n=2), type 2 (n=2), type 3 (n=16) and type 4 (n=5). Pronation deformity classified by Gshwind and Tonkin was evaluated as type 2 (n=2), type 3 (n=18) and type 4 (n=5). There was clinical correlation between severity of pronation contracture and impaired function of the thumb.

A total of 30 surgical interventions were performed (including five patients with spastic diplegia, sequentially on both upper limbs). In seven patients with hemiparesis, surgical treatment was accompanied by simultaneous intervention on the lower limb (Strayer procedure and guided growth by temporary epiphysiodesis).

Multilevel surgery led to better hand usage and better overall upper limb function (Table 1). Improvement of the functional capabilities of the upper limb, cosmetic appearance and ease of use were noted in all cases, as evidenced by an improvement in the functional class with regard to Van Heest classification (Table 2).

Table 1. Mean values of active ROM (Range of Motion) in the joints of the upper limbs preoperatively and in a long-term follow-up

Segment	Motion	Pre-operative period	Postoperative period*	
			Group 1 (spastic diplegia)	Group 2 (spastic hemiparesis)
Elbow	flexion/extension	148º/39º/0	147º/14º/0	152º/18º/0
Forearm	supination/ pronation	0/11º/81º	29º/0/50º	34º/0/52º
Wrist	dorsiflexion /palmar flexion	0/54º/86º	18º/0/69º	32º/0/57º
Thumb	adduction/abduction	45º/29º/0	31º/0/17º	25º/0/29º
	flexion/extension	76º/48º/0	54º/0/16º	50º/0/18º
	abduction/adduction	0/14º/56º	31º/0/36º	35º/0/33º

*Follow-up over 12 months

Table 2. Functional ability of the patients (by Van Heest classification)

Van Heest classification level	No of patients in the group			
	Group 1		Group 2	
	Preoperatively	Postoperatively	Preoperatively	Postoperatively
2	1		4	
3	5		5	
4	3	2	7	8
5		5		5
6		2		3

After a mean follow-up of more than 12 months (12-23 months), the whole patient cohort was found to have had significant improvement in their ranges of motion from a mean preoperative negative active supination of -11° to a mean postoperative supination of 29° in the group of spastic diplegia and 34° in hemiparesis patients ($p<0.03$) (Figure 4). No statistically significant difference between the groups regarding active supination and pronation movement was found. Probably this homogeneity of results was related to mild neurologic disorders classified as GMFCS level I-III in the whole cohort. Regarding maximal active dorsiflexion, after the surgery, there was a statistically significant improvement. The group 2 (spastic hemiparesis patients) showed better results in wrist extension.

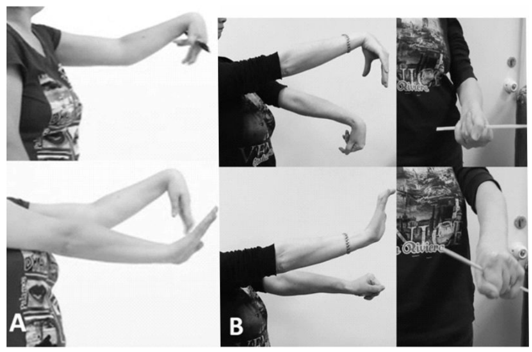

Figure 4. A female patient aged 36 years, left-side spastic hemiplegia. A) before surgery; B) active supination and dorsal flexion restored (Dr.Pliev M, 2016-2017)

We found no overcorrection complications in our cohort.

DISCUSSION

The significance of forearm pronation deformities in CP patients is not small. Aside from the aesthetics, a pronated forearm position associated with flexed wrist interferes with normal upper limb function. This excludes many important social and functional activities including handshaking, face washing, clapping and causes compensate bizarre postures and other body and shoulder movements (3,6,8). The orthopaedic surgery for contractures and deformities in upper limbs in CP patients aims to improve functional abilities, hygienic care and cosmetic appearance (9,17,18).

There are various orthopaedic conditions in upper limbs justifying reconstructive surgery (3,6,8,11,19,20). Pronation forearm contracture due to retraction of *M. pronator teres* and *M. pronator quadratus* is a common issue in CP patients (20-23). Restoration of active supination is recognized as an objective for orthopaedic surgery (13, 20-24). There is a variety of techniques to address the contracture including tendon and muscle releases, transposition of flexor and pronator tendons to extensors carpi, corrective detorsion osteotomies (8,18,20). But there is no clear consensus over how to optimally manage pronation deformities of the forearm in cerebral palsy patients yet.

The use of transfer of FCU to *M. extensor carpi radialis brevis* or *M. pronator teres* transfer remains controversial in the treatment for flexed wrist. Transposition of the flexor carpi ulnaris muscle can be advocated to improve dorsiflexion of the hand. The surgery was first described by Green (25) and was found efficient enough (9,22,23,26). According to Green, *M. extensor carpi radialis brevis/longus* is an optimal site for transposition of the *M. flexor carpi ulnaris* to ensure correction of the wrist flexion and ulnar deviation of the hand (25). On the other hand, Patterson et al. (26) reported occurrence of postoperative extension deformity of the wrist after this transfer.

Flexion contractures of the wrist and fingers are often present in CP patients (11). Flexion and adduction of the thumb coupled with flexion contracture of the wrist cause more serious functional concerns (7,14). Surgical treatment is primarily aimed at the correction of fixed contractures and establishment of a functional balance between spastic flexors and weak extensors (21). The transfer of the *flexor carpi ulnaris* solely fails to address flexion in the radiocarpal joint related to other shortened flexors of the wrist. Surgical options addressing the condition include aponeurotic release of short muscles and their Z-lengthening (11,13,27). Reported studies show related complications of surgical treatment. Length gain is difficult to control and there is a high risk of either under lengthening or overcorrection (18,26,28). This risk is particularly higher for wrist flexor lengthening in contrast to Z-lengthening of adductor pollicis longus and skin plasty (14).

This study has shown that the new technique of FCU transfer is highly effective in the management of pronation deformities of the forearm and flexed wrist in patients with cerebral palsy. Furthermore, this surgical technique not only releases the *M. flexor carpi ulnaris* as a deforming wrist flexion and cubital deviation force, but also transfers the *M. flexor carpi cubitalis* to the radius as a supinator force. The physiological reason of this transfer is related to the fact that CP patients are likely to actively use the *flexor carpi ulnaris* for functional needs (13,29). In comparison with our previous series (30), this study refined indications for FCU transfer: highly restricted or lost active forearm supination, total *M. supinator* impairment. On the other hand, FCU release in combination with *shortening of the extensor pollicis longus and the extensor pollicis brevis tendons* ensured active wrist extension. Results of our series justify surgical approach to address contracture and deformities in upper limbs in CP patients to improve functional abilities. The choice of technique and prognosis of the results rely on the level of neurological deficiency and motivation of a patient to use the operated limb (2,3,8,19). Unfortunately, a satisfactory functional outcome cannot be expected in patients with an IQ less than 70 (27).

Limitations of this study are the small number of patients and relative heterogeneity of the series.

The new technique of FCU transfer to the radius has been shown to be an effective method to address pronation contracture of the forearm joints and can be used in combination with other elements of surgical intervention for elbow and thumb contractures. The FCU rerouting and transfer to distal radius is a good option in the absence of active supination. Distal release of FCU weakening flexion forces with a simultaneous procedure restoring active wrist extension provides satisfactory outcomes in the treatment of associated flexed wrist contracture.

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TRANSPARENCY DECLARATION

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