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ORIGINAL ARTICLE

Hand function after muscle transfer in spastic hemiparesis patients

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Abstract
Introduction and Objective. In spastic hemiparesis, upper extremity issues pose challenges for orthopaedic surgeons, neurologists, physiotherapists, and occupational therapists. Various interventions aim to decrease contractures, improve hand function, and enhance mobility. The aim of the study was evaluation of hand function after tendon transfer in spastic hemiparesis in cerebral palsy.
Materials and Method. A retrospective review was performed of in- and outpatient charts (from 2006) across two centres: a referral facility for cerebral palsy and a paediatric orthopaedic clinic. Inclusion criteria was spastic hemiplegia of the upper limb, treated surgically with muscle transfer. Exclusion criteria were dystonia or other coordination disorders, bilateral involvement, or prior upper limb surgeries. Minimum follow-up – 2 years.
Results. Thirty patients (14 females, 16 males) met the criteria; mean surgery age – 11.5 years (range 10–15). All were GMFCS II or III and MACS 2 or 3, with extrinsic-type hands per Zancolli (14 group 1, 10 group 2a, 6 group 2b). All initially underwent ray plasty, FCU-to-ECRL transfer, and pronator teres release. Two had biceps lengthening; one had finger flexor myotomy. All reported self-perceived functional gains (e.g., improved grasp, pencil holding, self-feeding), verified by therapists. Hand and forearm alignment improved without MACS classification change; function according to Zancolli classification improved.
Conclusions. Muscle transfer surgery improved upper extremity position and function in spastic hemiplegic patients. The group for surgery has to be carefully selected. There is a need of standardization of reporting goals and outcomes in this selected population, as well as choosing the procedure required by an experienced team.

Key words
child, orthopaedics, hemiplegia, cerebral palsy, upper extremity, tendon transfer

INTRODUCTION

Cerebral palsy (CP) is damage to the brain – lesions of the upper motoneuron, which occurs before, during or after the delivery (up to 2 years) [1]. There are different manifestations of CP – depending on the sites involved: unilateral, paraplegic, hemiplegic or quadriplegic. In addition, there are different types of manifestation: spastic, hypotonic (rare), dystonic, athetotic, dyskinetic or mixed. There is a wide range of involvement, from discreet to highly involved cognitive capabilities and movement possibilities.

Muscle spasticity in cerebral palsy is a symptom of upper motor neuron syndrome, characterised by excessive muscle tone and exaggerated stretch reflexes that lead to muscle stiffness, reduced motor function and changes in muscle morphology, such as reduced muscle volume and length [2]. The majority of children with CP exhibit a spastic motor type, muscle stiffness increases proportionally to the velocity of induced stretch [3]. Children with cerebral palsy may have difficulty holding and manipulating objects, and they also have difficulty with fine motor skills such as writing, tying their shoes or even doing simply day hygiene care. The most important aim in treatment children with cerebral palsy for parents in first years of kid's life is decreasing joints contracture and improving function, for ex. walking possibilities and upper extremity skills. The hand function recedes into the background and physical therapy and bracing is useful at this time.

Surgical treatment of the upper extremity in cerebral palsy, including soft tissue releases, tendon transfers, and joint stabilization, can improve functional use. The classic paper by Mowery et al. states that the surgical treatment of spastic deformities in the upper extremities of patients with cerebral palsy can lead to improved function, even if the gains are small [4]. The key surgical concepts are to release spastic deforming muscles and use augmentation tendon transfers to maintain an improved functional position. Tendon transfers that use muscles that contribute to the deformity are preferred, as they will function to correct the deformity without extensive post-operative training.

As presented by Van Heest et al., for children with upper-extremity CP who were candidates for standard tendon transfer, surgical treatment was demonstrated to provide greater improvement, of modest magnitude, than botulinum toxin injections or regular, ongoing therapy at 12 months of follow-up using the Shriners Hospital Upper Extremity Evaluation dynamic positional analysis (SHUEE DPA) [5].

The most common pattern of upper-extremity positioning is flexion of the elbow, forearm pronation, wrist flexion, and thumb in palm [1]. Surgical reconstruction involves

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transferring the flexor carpi ulnaris (FCU) to the extensor carpi radialis brevis (ECRB), which reduces spastic wrist flexion caused by the FCU, increases wrist-extension power, consequently improving wrist position.

There is a lack of papers meta-analyzing groups of patients in long follow-up after muscle tendon transfer. In properly selected patient groups, these procedures provide the patients with long-term, lasting good functional results [6–8].

OBJECTIVE

The aim of the study is to assess the functional outcome of upper extremity surgical procedures in cerebral palsy patients. The surgery is intended to help to balance the weaker extensors muscle with stronger flexors [9]. There are several papers describing evaluation of upper extremity motion and position in a more general way [10–12], while others concentrate more on the predictors of isolated muscle release or redirection [13–18].

Operations, including simultaneous correction of forearm, wrist, and thumb deformities, are commonly recommended but rarely evaluated. There are studies which have attempted to evaluate improvement in daily activity following these procedures using dedicated various outcome measurement tools [19–22]. The current study evaluates hand function – range of motion and functional status according to the Zancolli scale and MACS after simultaneous surgery of wrist flexor, finger flexors, and first ray of the hand.

MATERIALS AND METHOD

The study was conducted after approval by the bioethical committee. The study was approved by the Ethical Committee at the Medical University of Łódź, Poland (Approval No. RNN/258/16/KE), and the research conducted in full compliance with the ethical standards of the Declaration of Helsinki. All participants were informed about the purpose of the study and provided written informed consent prior to participation.

The study is a retrospective chart review of prospectively collected data from patients treated at two centres: the Paediatric Orthopaedic Clinic at the University Hospital and the Referral Centre for Cerebral Palsy. Over 200 paediatric encounters per year were included of orthopaedic hospitalizations, inpatient and outpatient physiotherapy sessions, and additional outside physical therapy centres throughout the central and central-eastern part of Poland (which has a total population of more than 4 million) with a diagnosis of cerebral palsy. All in- and outpatient charts in the hospital databases from 2006 – 2020 were reviewed (Fig. 1). Inclusion criteria for the study – spastic hemiplegia in upper extremity treated with surgical muscle transfer. Exclusion criteria – dystonia or other muscle coordination disorders, both hands involvement, and other upper extremity surgery before muscle transfer. Minimal follow-up – 2 years.

Demographic data were collected (age, gender, type of paralysis), hand position and range of motion (ROM). Based on reports, GMFCS (Gross Motor Function Classification System), MACS (Manual Ability Classification System), and the Zancolli classifications were analysed [10, 11, 22].

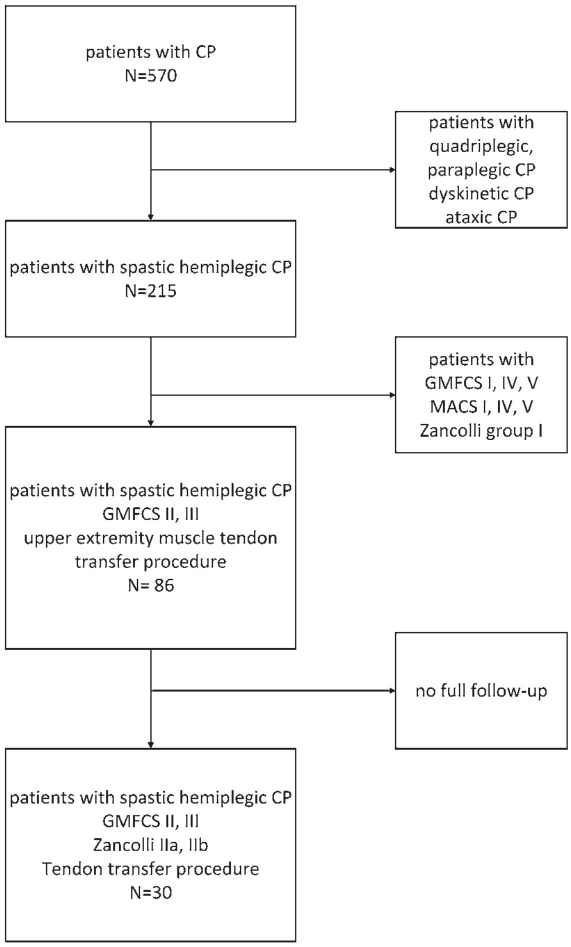

Figure 1. Flowchart illustrating the patient selection and stratification process for the study

Shapiro-Wilk test was used to evaluate the distribution of samples. Because this was found to be not normally distributed for all tested samples, the Wilcoxon-Mann-Whitney test was used to evaluate the differences between the medians of the analyzed results. A p value of less than 0.05 was estimated as the significance threshold.

RESULTS

Thirty patients met inclusion criteria – 14 females and 16 males. The mean age at surgery was 11.5y (range 10–15). Ten patients had left hemiparesis (33%). All patients were classified as GMFCS II (21 patients) or III (9 patients), upper extremity functions MACS 2 (19 patients) and 3 (11 patients). All hands were classify into extrinsic type according to the Zancolli classification. Fourteen hands were in group 1, 10 in group 2a and 6 in group 2b. The median follow-up was 7 years 9 months with range 2–14 years.

All operations were performed by the senior author (AG) and another author (ŁM). All patients underwent first ray plasty, flexor carpi ulnaris muscle (FCU) on extensor carpi radialis longus muscle (ECRL) transfer, and pronator teres muscle release. The first ray plasty involved the skin 'Z' plasty and muscle myotomy–adductor pollicis muscle and flexor pollicis brevis muscle. In two cases, additional biceps muscle lengthening was performed. One child had finger flexor myotomy and one case had all these procedures performed.

Table 1. Upper extremity range of motion (active/passive) before and after surgery.

	Before surgery				After surgery				p active	p passive
	Active		Passive		Active		Passive			
	Median	Min-max	Median	Min-max	Median	Min-max	Median	Min-max		
wrist flexion	83°	70–90°	87°	80–90°	84°	70–90°	84°	70–90°	0.341	0.814
wrist extension	10°	0–20°	57°	45–80°	32°	10–40°	32°	10–40°	<0.001	0.007
wrist pronation	82°	70–90°	86°	80–90°	78°	50–90°	78°	50–90°	0.15	0.988
wrist supination	12°	0–20°	66°	45–90°	59°	40–80°	59°	40–80°	<0.001	<0.001
thumb abduction	6.25	0–10	31	20–40	26°	20–40	40°	35–45°	<0.001	<0.001
MCP I extension	-10°	-20 – 0°	-1,5°	-10–0°	-6°	-15 – 0	-0,2°	-15–0°	0.008	0.115
IP extension	-10°	-20 – 0°	-1,9°	-10 – 0°	-5,6°	-10 – 0	-0,4°	-5 – 0°	0.003	0.06

After surgery, the patients were immobilised in a cast for 4–6 weeks in the position of possible max extension in the elbow joint, possible max forearm supination, possible max thumb abduction and finger extension in neutral position. No problems with cast or skin were reported.

Active elbow range of motion did not change either before and after surgery – flexion 120–140°, extension -5 -20°. The wrist position at rest changed from median 58° flexion (range: 45–70°) to median 8.5° extension (range: -10 – 20°) (Tab. 1).

All patients demonstrated self-reported improvement in function and daily activity, confirmed by physical therapy staff on the basis of short outpatient visit. However, there were very non-homogeneous descriptions of improvement. Better grabbing, pencil holding, easier self-feeding, etc., were reported, as well as improved hand and forearm position, confirmed by both patients and caregivers. The patients therefore achieved the intended gaols – more functional hand position with more functional upper extremity motion. Strength of the grip, however, was not so important for them. They reported that the most significant improvement was holding a cup, self-feeding, holding a smartphone, holding a pencil. These observations were confirmed in statistical analysis (Tab. 1). Besides wrist flexion and pronation, improvement was observed in the range of motion after surgery (active and passive, statistically significant). The hand position was also improved from the cosmetic point of view, which was very important for most patients and caregivers. During the study, it was observed that the children stayed at the same level of MACS.

However, when reassessing the functions and movement of the hand according to the Zancolli classification, changes were observed after surgical treatment. All patients qualified to group 1 before surgery, as well as after surgery, were classified to group 1. Out of 10 patients from group 2a, 7 patients were classified to group 1 after treatment. All patients from group 2b were classified to group 2a after surgery (Tab. 2).

Table 2. Functional group assignment of patients (Zancolli classification) pre- and post-surgery.

Pre-operative Zancolli group		Post-operative Zancolli group	
I	N = 14	I	N = 21 (14 + 7 from IIa)
II a	N = 10	II a	N = 9 (3 + 6 from IIb)
II b	N = 6	II b	N = 0

DISCUSSION

Although the study does not directly concern patients from rural areas (this was neither assessed during the evaluation of patient documentation nor considered during discussions with caregivers), the centres that conducted the research are located in regions where 1.9 million people reside in rural areas, including 376,000 children (data from GUS 2024 – Statistical Yearbook of Agriculture) [23]. The literature indicates a correlation between the prevalence, time to diagnosis, and limited access to treatment in children with CP from rural areas, and therefore a lower-income population.

A higher prevalence of CP was associated with male gender, low income, and rural residential location [24]. Research also suggests that cerebral palsy (CP) in rural areas may be associated with unique challenges. Children from rural communities are diagnosed with CP significantly later than those from urban areas, potentially impacting early intervention [25]. A study in a rural area found that perinatal risk factors, such as preterm birth, low birth weight, birth asphyxia, and neonatal seizures, were significantly associated with CP development [26]. These findings suggest that rural location may influence various aspects of CP occurrence, diagnosis, treatment, and family support.

Hand surgery may be considered for individuals with cerebral palsy if they have severe hand deformities that are causing functional limitations or pain,or are not cosmetically acceptable. Hand and upper limb surgeries for cerebral palsy may include tendon transfers, tendon lengthening, joint stabilization procedures and soft tissue plastic surgery. In the current study, the aim of the surgery was the restoration of balance between antagonist flexor and extensor muscles. This allowed a neutral forearm position and permitted thumb opposition, which resulted in a pinch grip between the thumb and index finger. Restoration of extrinsic digital flexor muscles, allows children to hold an object in the palm [27]. Louwers et al. in their meta-analysis of 12 studies noted the ability and perception of the patient to use the hand(s) and perform activities improved significantly after upper extremity surgery.

However, there is still lack of good quality of evidence for the effects of surgery on activities and participation of children and adolescents with CP [28]. In the current study, the patients were followed-up from 2 – 14 years (median 7 years 9 months) after surgery. In all cases, the results of surgery were permanent.

Van Heest et al. reviewed 13 patients after upper extremity surgery, using motion analysis and EMG, and mean follow-up of 3.6 years. They conclude that tendon transfers, especially for wrist extension, can be beneficial in improving hand and wrist position. Nevertheless, surgery did not improve hand function in more involved patients, even if the position was improved [29]. Piscitelli et al. made a meta-analysis of widely-used functional scales, including the MACS classification which is designed to classify how children with CP use their hands when handling objects in daily activities. Piscitelli and Fitoussi also claim that children remain at the same level as prior to surgery [30, 31]. Also in the current study, no change was observed in belonging to a particular group according to the MACS classification. However, according to the Zancolli classification, changes we noticed after surgery. The improvement of the ability to hold the hand, extension of the fingers and wrist resulted in qualifying to a higher group. This classification, however, assesses only the ability to extend the wrist and fingers, without assessing the function of the hand. It seems that the lack of changes in the MACS classification and the improvement in the Zancolli classification may be due to the fact that the most important movement stereotypes are developed by the age of 7, while the patients in the observed group were operated after the age of 10.

One of the procedures published in the literature is pronator teres rerouting [32]. In the presented study, however, pronator teres muscle release was preferred, a choice may be drive the good range of elbow motion in the patients. The authors consider that muscle release plays a dual role: firstly, by decreasing the power of flexors of elbow joint muscles, and secondly, by decreasing forearm spastic pronation.

An article review performed by Van Munster et al. summarized that surgery may improve grip strategy and induce an increase in the repertoire of other grips and spontaneous use of the hand, without affecting daily life activities. The problem of better hand position after tendon transfer, however, was not solved, although it was suggested that it may improve muscle coordination [33]. The authors of the current study agree with that conclusion because the improvement remains rather subjective, and based on the assumptions of patients, family, and surgeons.

Louvers et al. in their systematic review reported worsening in hand function in a proportion of patients with cerebral palsy after longer follow-up, which suggests a deteriorating effect due to ageing. Also, Novak et al. suggest that in order to avoid a long-term loss of function, it is necessary to develop a standard relapse protocol with an emphasis on non-operative treatment, ranging from training-based interventions, through orthosis to botulinum toxin injections [17]. They encourage the involvement of the adolescent in decisions about whether and how hand function can be further improved [34]. In the current study, all patients at the time of surgery were 10-years-old, or older. Based on observation, the authors assert that conscious patient cooperation in physical therapy is essential for final success, and the best cooperation with children starts after 10 years of age.

Children with mental disabilities and children with severe hand impairment have rather limited goals, whereas increased mobility may prevent contractures and facilitate activities of daily living. For those exhibiting mildly impaired hand functions, the functional grasp improved after tendon transfer and muscle release. More functional positions improved skills in the one hand as well as in daily activities.

The presented study demonstrates that almost all children experienced improvement in the use of the impaired hand. In recent studies, the measurements of outcomes have included the dynamic positioning part of the Shriner's Hospital Upper Extremity Evaluation (SHUEE) [35], assessment of the functional use of the upper extremity, or the Assistive Hand Assessment. These scales indicate the need for involvement of a multidisciplinary team [36]. Each of these tests measures a different aspect of hand function after tendon transfer surgery in CP. Unfortunately, the authors of the current study do not have access to a specific hand therapist, and consider the lack of objective measurement as a weak point of the study.

Limitations of the study. This study has several other limitations that warrant consideration. Firstly, the small sample size inherent to the study design restricts the generalizability of the results obtained. Additionally, the retrospective nature of the data collection and the absence of standardized, objective, outcome measures may have introduced bias in the evaluation of functional improvements. Furthermore, the heterogeneity in patient follow-up durations and variations in the severity of spasticity also limit the consistency of the conclusions. Also, the use of only three tools (range of motion, Zancolli scale and MACS) to assess the results of surgery, provides only a partial view on the outcome of the patients' treatment.

Although the study spans data collected from 2006 – 2020, the final sample size was constrained by strict inclusion criteria (e.g., isolated spastic hemiplegia treated with surgical muscle transfer without previous upper extremity surgeries). Statistically, CP occurs in 2.08/1000 live births in Europe (Surveillance of Cerebral Palsy in Europe) [37]. The number of live births in Poland has been declining over the years, remaining at an average of 389,000 per year during the analyzed period. The hemiplegic form occurs in only 1-in-3 children with CP [33]. Furthermore, the severity of spasticity affecting children with hemiplegia varies depending on the extent of CNS damage. Milder cases are successfully treated non-operatively, according to Zancolli guidelines, which also contributes to a reduced pool of patients undergoing surgery. Also, according to the Zancolli classification, patients classified to group 3 are poor candidates for surgeries aimed to improve function. All of this means that after applying the inclusion criteria, analyzing the documentation, excluding patients with the most severe forms of CP, and rejecting incomplete records, the study group consists of only 30 patients.

Function, based on flexed position can benefit from surgery. However, their families need do have an experienced occupational therapist to find attainable and purposeful objectives adapted to the severity of the children disability. The procedure should be performed by a team of experienced neuroorthopedic surgeons.

Future research with larger, more homogeneous cohorts, prospective designs and dedicated assessment tools, are needed to obtain more comprehensive results.

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