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Restoration of active elbow flexion by pectoralis major transfer in children with amyoplasia

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Abstract

Introduction Amyoplasia is the most common type of arthrogryposis multiplex congenita. Some patients may lack active elbow flexion due to aplasia of the forearm flexor muscles. **The objective** was to identify the optimal age for pectoralis major muscle transfer to improve elbow flexion in children with amyoplasia and estimate outcomes of the procedure depending on the level of spinal cord injury. **Material and methods** Restoration of active elbow flexion was performed for 34 children with amyoplasia (39 upper limbs) between 2011 and 2020 using partial monopolar pectoralis major muscle transfer. The age of patients ranged between 1.5 and 15.5 years (6.24 ± 4.24 years). The patients were divided into 3 groups depending on the level of spinal cord injury: C6–C7 (n = 4; 11.8 %), C5–C7 (n = 24; 70.6 %), C5–Th1 (n = 6; 17.6 %). The outcomes were estimated at 6 to 99 months (44.53 ± 31.72 months). The patients underwent preoperative and postoperative clinical and neurological examination. The results were statistically analyzed. **Results** Active elbow flexion improved by 56.8 degrees ($p < 0.0001$), forearm flexor muscles strengthened by 2.0 points ($p < 0.0001$) and extension deficit improved by 14.5 degrees ($p < 0.0001$) were postoperatively statistically significant. Results were rated as good in 15 (38.5 %); as fair, in 8 (20.5 %) and poor in 16 (41 %) cases. Greater differences were found between the group of patients with the level of C6-C7 spinal cord injury in relation to the group of patients with the level of C5-Th1 ($p < 0.05$). There were no statistically significant differences between patients with C6–C7 and C5–C7 lesion levels ($p > 0.05$). Children of different age groups showed no differences in the results of treatment ($p > 0.05$). **Conclusion** Pectoralis major muscle could be used for active elbow flexion restoration in patients with amyoplasia. The best results were observed in patients with C6–C7, C5–C7 segmental lesions of the spinal cord. There was no correlation between age of patient at the time of surgery and the effectiveness of operation.

Keywords: amyoplasia, arthrogryposis, elbow, muscle flaps, spinal cord

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INTRODUCTION

Arthrogryposis multiplex congenita is a term used to describe a group of congenital diseases characterized by congenital joint contractures of two or more segments [1]. The occurrence of arthrogryposis is associated with restriction of fetal movements (fetal akinesia), and there is a correlation between the severity of contractures and the period of restricted motor activity: the longer the period, the more severe the contractures. Loss of fetal muscle function results in fetal akinesia and, secondarily, in joint contractures. Restricted motion in the joints leads to secondary muscle atrophy and the development of contractures [2]. Amyoplasia is the most common type of arthrogryposis which is a sporadic non-progressive disease characterized by muscle hypoplasia or aplasia, multiple contractures and impaired motor neurons of the spinal cord. Clinical manifestations in the upper extremities include intrarotational contractures in the shoulder joints, extension contractures in the elbow joints, flexion contractures of the wrist, fingers, flexion-adduction contracture of the thumb, limited or inability of self-care. Patients can have aplasia of the forearm flexors that results in impaired active flexion and severe functional disorders. The goal of treatment is to ensure their independence in daily life, independent eating and personal hygiene [3]. The pectoralis major muscle (PM) is commonly used to restore active elbow flexion [4–13]. Single publications reporting the PM transfer for elbow flexion in patients with amyoplasia, the lack of data on the optimal age for performing a surgical intervention, on the outcomes depending on the level of spinal cord injury have determined the relevance of the research topic. The objective was to identify the optimal age for pectoralis major muscle transfer to improve elbow flexion in children with amyoplasia and estimate outcomes of the procedure depending on the level of spinal cord injury.

MATERIAL AND METHODS

Active elbow flexion was restored in 34 children with arthrogryposis (39 upper limbs) by partial monopolar PM transfer performed at the FBGU Turner NIDOI between 2011 and 2020. The age of patients ranged from 1.5 to 15.5 years (6.24 ± 4.24 years) at the time of surgery. The children were divided into 4 age groups:

1–3 years old (n = 13; 38.2 %), 3-7 years old (n = 9; 26.5 %), 7–11 years old (n = 7; 20.6 %), 12–18 years old (n = 5; 14.7 %). Patients were divided into 3 groups according to the level of spinal cord injury: C6–C7 (n = 4; 11.8 %), C5–C7 (n = 24; 70.6 %), C5–Th1 (n = 6; 17.6 %). Outcomes were evaluated at 6 to 99 months (the mean – 44.53 ± 31.72 months). Three groups of patients were identified analyzing the results of PM transfer to improve elbow flexion: the follow-up of 6 months to 1 year (n = 7; 20.6 %), 1–3 years (n = 11; 32.4 %) and more than 3 years after the operation (n = 16; 47 %). All patients and/or their legal representatives voluntarily signed an informed consent to participate in the study, perform surgery and publish personal data. The study was approved by the local ethical committee (Protocol No. 19-3 dated December 9, 2019).

Patients were examined preoperatively, at 6 months and over. Physical examination of patients included assessment of elbow motion (active and passive), the strength of the forearm flexors and the donor area, the ability to perform basic self-care skills and the use of compensatory-adaptive movements. The child's basic motor skills were assessed with physical examination, video at the stages of treatment and the subsequent analysis. The range of motion in the elbow joint was measured with a goniometer. Muscle strength was assessed on a six-point scale (from 0 to 5 points) when moving on a plane, overcoming gravity and with manual resistance. The level of segmental lesions of the spinal cord was identified with neurological examination of the child.

Statistical data processing was carried out using the Statistica 10 and SAS JMP 11 software packages. The mean value and standard deviation “M ± SD” were used to describe the numerical scales. Descriptive statistics for nominal variables were presented as absolute (relative) frequencies. The charts for quantitative parameters had the arithmetic mean indicated by a dot, the median indicated by a horizontal segment, the intraquartile range indicated by a rectangle, the minimum and maximum values indicated by vertical segments. Comparisons of two groups on numerical variables were performed using the nonparametric Mann-Whitney test. The nonparametric Kruskal-Wallis test was used to compare three or more groups quantitatively. Statistical significance of group differences on binary and nominal scales was determined using Pearson's Chi-square test for independent groups and the McNemar's test for dependent groups. The difference in the variables at the significance level of $p < 0.05$ (95 %) was considered statistically significant testing statistical hypotheses. Absent or limited active elbow flexion (less than 90°), passive flexion of 90° or more, PM strength of 3 points or more, deficient elbow extension of less than 40 ° were indications for restoration of active elbow flexion by partial monopolar PM transfer.

PM transfer was performed with the method we modified using techniques described by J. Chomiak, P. Dungl (2008) that consisted in moving the distal part of the PM (sternocostal, costal and abdominal portions) to the n. pectoralis medialis and a. thoracoacromialis [8]. The muscles were harvested together with a part of the rectus aponeurosis, moved to the anterior surface of the forearm and fixed with transosseous sutures to the radial shaft of the tuberosity with the elbow supinated and flexed at 150–160°. The limb was immobilized with a plaster splint from the fingertips to the upper third of the contralateral shoulder for 4 weeks. Restorative treatment including exercise therapy, massage, electrical muscle stimulation and robotic mechanotherapy (ARMEO) were recommended for the patients.

RESULTS

Preoperative passive elbow flexion measured 90 to 130° (104.12 ± 12.40), active flexion ranged from 0 to 70° (15.59 ± 16.28), elbow extension ranged from 0 up to 30° (7.24 ± 8.82), forearm flexor strength was 0–1 points and PM strength measured 3–4 points. Passive elbow flexion did not change and ranged from 90 to 130° (104.12 ± 12.40), active flexion from 0 to 120° (71.94 ± 33.40), elbow extension ranged from 0 to 40° (21.70 ± 12.27), forearm flexor strength was 2–5 points (2.85 ± 1.08) at 6 months and over.

Statistically significant changes were observed postoperatively in active flexion (by an average of 56.8 degrees; $p < 0.0001$), forearm flexion strength (by an average of 2.0 points; $p < 0.0001$), deficient extension” (on average by 14.5 degrees; $p < 0.0001$) (Table 1). Postoperative elbow extension deficit increased in 30 cases (76.9 %) and did not lead to impaired self-care.

Table 1

Results of partial monopolar PM transfer to improve elbow flexion in children with arthrogryposis

Description	M ± SD		p
	preoperatively	postoperatively	
Passive flexion, degrees	104.12 ± 12.40	104.12 ± 12.88	1.0000
Deficient extension, degrees	7.24 ± 8.82	21.70 ± 12.27	< 0.0001
Forearm flexor strength, points	0.85 ± 0.61	2.85 ± 1.08	< 0.0001
Active flexion, degrees	15.59 ± 16.28	71.94 ± 33.40	< 0.0001

A scale modified by A. Van Heest was used postoperatively to measure active elbow flexion, deficient elbow extension, the strength of the forearm flexors, compensatory-adaptive mechanisms for basic self-service skills. [4, 14, 15]. The results were rated as good in 15 (38.5 %), fair in 8 (20.5 %), poor in 16 (41 %) cases (Fig. 1).

Table 2 shows that patients of the three groups with different levels of spinal cord injury had statistically significantly differences in the preoperative strength of the forearm flexors and the magnitude of active elbow flexion. There were statistically significant differences between the groups postoperatively in a number of parameters, with the greatest differences found between the group of patients with the level of C6-C7 spinal cord injury and the patients with the C5-Th1 level in terms of "Amplitude of movement" (an average of 44, 2 degrees; p = 0.0048), "Score on the scale" (by an average of 1.8 points; p = 0.0131), "Forearm flexor strength" (by an average of 2.7 points; p = 0.0003), as well as "Active flexion" (by an average of 71.5 degrees; p = 0.0011). Multiple pairwise comparisons of groups did not reveal statistically significant differences postoperatively between patients with C6–C7 and C5–C7 injury (p > 0.05), and statistically significant differences were noted in the forearm flexor strength and active elbow flexion (p < 0.05) (Tables 3, 4) between groups “C5–C6” and "C5-Th1", and "C5-C7" and "C5-Th1". No statistically significant differences were found between the groups (p > 0.05) comparing patients of the three groups by age at the time of surgery, and by the follow-up period (Tables 5, 6).

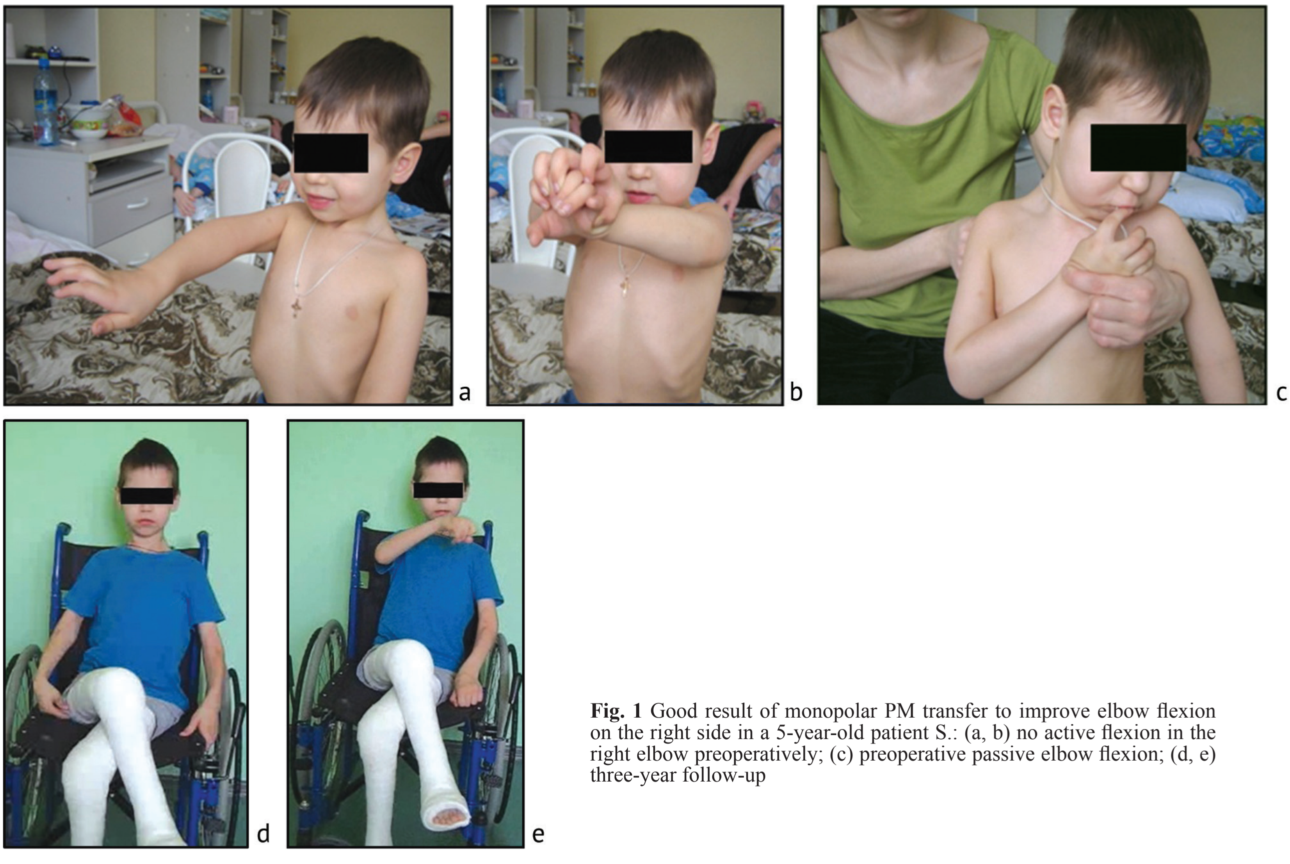

Fig. 1 Good result of monopolar PM transfer to improve elbow flexion on the right side in a 5-year-old patient S.: (a, b) no active flexion in the right elbow preoperatively; (c) preoperative passive elbow flexion; (d, e) three-year follow-up

Table 2

Comparison of three groups of the variable "Level of spinal cord injury" in terms of preoperative quantifications (mean ± standard deviations)

Description	Level of spinal cord injury			Level p (df = 2)
	C6–C7 (n = 4)	C5–C7 (n = 24)	C5–Th1 (n = 6)	
Passive flexion, degrees	105.00 ± 12.91	106.04 ± 12.94	95.83 ± 6.65	0.1756
Deficient extension, degrees	12.75 ± 9.14	7.50 ± 9.30	2.50 ± 3.67	0.1677
Forearm flexor strength, points	1.50 ± 0.58	0.92 ± 0.50	0.17 ± 0.41	0.0018
Active flexion, degrees	17.50 ± 5.00	18.54 ± 17.88	2.50 ± 3.67	0.0090

Table 3

Comparison of three groups of the variable "Level of spinal cord injury" in terms of postoperative quantitative parameters (mean ± standard deviations)

Parameter	Level of spinal cord injury			p value (df = 2)
	C6–C7 (n = 4)	C5–C7 (n = 24)	C5–Th1 (n = 6)	
Passive flexion, degrees	105.00 ± 5.77	106.46 ± 13.87	94.17 ±9.17	0.1249
Deficient extension, degrees	25.00 ± 5.77	23.33 ± 17.15	22.67 ±11.34	0.9133
Scale score, points	3.50 ± 1.00	2.96 ± 0.91	1.67 ± 0.82	0.0131
Forearm flexor strength, points	4.00 ± 0.82	3.04 ± 0.75	1.33 ± 0.82	0.0003
Active flexion, degrees	92.50 ± 22.17	81.25 ± 25.89	21.00 ± 10.77	0.0011

Table 4

Multiple pairwise comparisons of the variable "Level of spinal cord injury" postoperatively

Passive flexion, degrees	Level p		
	C6–C7 – C5–C7	C6–C7 – C5–Th1	C5–C7 – C5–Th1
Scale score, points	0.9923	0.4316	0.1408
Forearm flexor strength, points	0.9372	0.9932	0.9664
Active flexion, degrees	0.6561	0.0513	0.0617
Passive flexion, degrees	0.2612	0.0018	0.0086
Deficient extension, degrees	0.8071	0.0115	0.0026

Table 5

Comparison of three groups of patients with different levels of spinal cord injury in terms of quantitative parameters (age at the time of surgery and follow-up) (mean ± standard deviations)

Parameter	Level of spinal cord injury			p value (df = 2)
	C6–C7 (n = 4)	C5–C7 (n = 24)	C5–Th1 (n = 6)	
Age at the time of surgery, years	6.50 ± 3.03	6.56 ± 4.47	4.75 ± 4.25	0.4184
Follow-up period, months	58.75 ± 28.63	39.04 ± 32.13	57.00 ± 30.08	0.1597

Table 6

Multiple pairwise comparisons of patients according to the variable "Level of spinal cord injury" depending on age at the time of surgery and follow-up time

Parameter	p		
	C6–C7 – C5–C7	C6–C7 – C5–Th1	C5–C7 – C5–Th1
Age at the time of surgery, years	0.8843	0.4835	0.5351
Follow-up period, months	0.3120	0.9584	0.3788

Analysis of the dynamics in the quantitative parameters for the variable "Level of spinal cord injury" revealed a postoperative increase in Flexion deficiency, Forearm flexor strength, Active flexion as compared to preoperative measurements ($p < 0.05$). Deficient flexion ranged from +96.1 % to +806.7 % in the groups. An increase in this parameter in the postoperative period in relation to preoperative period was registered for three groups: by 96.1 %, 211.1 % and 806.7 % (Fig. 2, 3). Fluctuations in the dynamics of the Forearm flexor strength ranged in the groups from +166.7 % to +700.0 %. An increase in the postoperative parameter in relation to the preoperative measurements was registered for all groups by 166.7 %, 231.8 % and 700.0 %, respectively (Fig. 4, 5).

Fluctuations in the dynamics of the active flexion ranged in the groups from +338.2 % to +740.0 %. The postoperative active flexion increased by 428.6 %, 338.2 % and 740.0 % in three groups (Fig. 6, 7). Table 7 presents the results of a statistical analysis with comparison of preoperative quantitative parameters in patients of four age groups.

Table 7 demonstrated that preoperative parameters in patients of different age groups were significantly different only in the Forearm flexor strength ($p = 0.0331$). Tables 8, 9 showed no statistically significant differences between the four groups. Tables 10, 11 present the results of the statistical analysis of the three groups of patients at different follow-up periods.

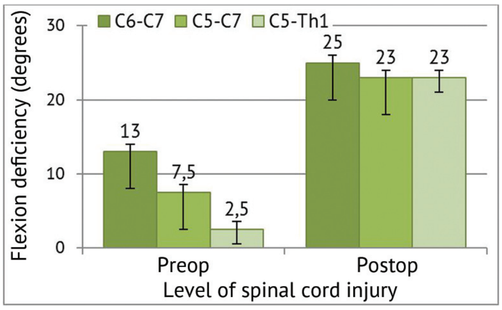

Fig. 2 Dynamics in the flexion deficiency (degrees) in patients with different levels of spinal cord injury

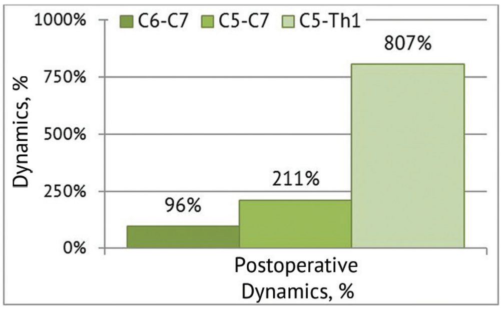

Fig. 3 Dynamics in the flexion deficiency (percentage) in patients with different levels of spinal cord injury

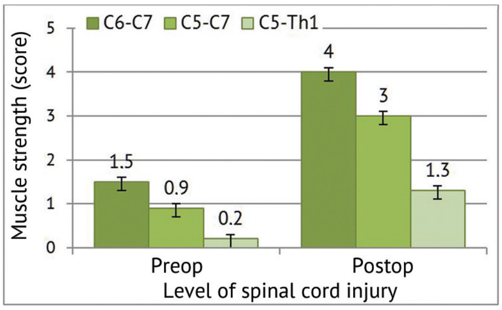

Fig. 4 Dynamics in the forearm flexor strength (score) in patients with different levels of spinal cord injury

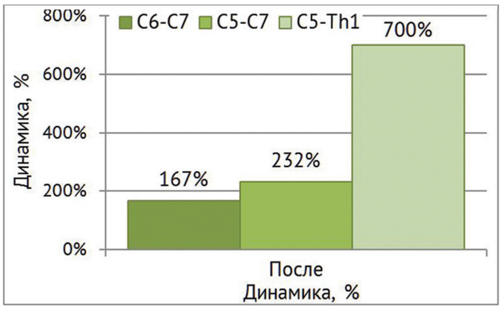

Fig. 5 Dynamics in the forearm flexor strength (percentage) in patients with different levels of spinal cord injury

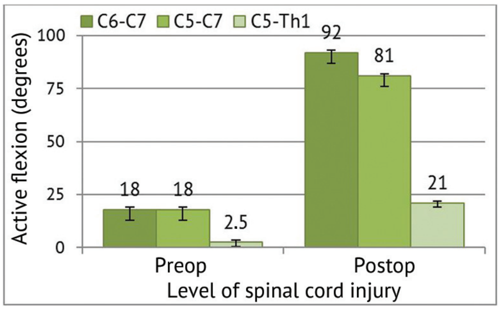

Fig. 6 Dynamics in active flexion (degrees) in patients with different level of spinal cord injury

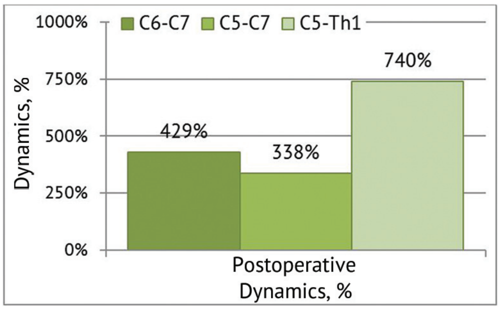

Fig. 7 Dynamics in active flexion (degrees) in patients with different level of spinal cord injury

Table 7

Postoperative comparison of quantitative parameters in patients of four age groups with regard to preoperative level (mean ± standard deviations)

Parameter	Age group				p value (df = 3)
	1 (n = 12)	2 (n = 9)	3 (n = 7)	4 (n = 5)	
Passive flexion, degrees	108.33 ± 13.54	101.11 ± 9.28	104.29 ± 13.97	98.00 ± 13.04	0.4291
Deficient extension, degrees	4.08 ± 6.10	8.44 ± 11.53	9.71 ± 8.83	10.40 ± 9.50	0.4118
Forearm flexor strength, points	0.58 ± 0.51	0.89 ± 0.60	1.43 ± 0.53	0.60 ± 0.55	0.0331
Active flexion, degrees	12.17 ± 19.61	16.00 ± 22.64	18.57 ± 3.78	18.00 ± 4.47	0.0821

Table 8

Comparison of the results of treatment depending on the age at the time of surgery (mean ± standard deviations)

Parameter	Age group				p value (df = 3)
	1 (n = 12)	2 (n = 9)	3 (n = 7)	4 (n = 5)	
Scale score, points	2.75 ± 1.22	3.11 ± 1.05	3.00 ± 1.00	2.20 ± 0.45	0.3922
Passive flexion, degrees	110.83 ± 13.95	97.78 ± 10.93	104.29 ± 11.34	98.00 ± 13.04	0.1224
Deficient extension, degrees	25.50 ± 12.15	23.44 ± 13.01	28.00 ± 21.36	16.40 ± 14.64	0.7817
Forearm flexor strength, points	2.67 ± 1.23	3.00 ± 1.22	3.14 ± 1.07	2.80 ± 0.45	0.7984
Active flexion, degrees	68.42 ± 41.21	74.44 ± 35.04	87.86 ± 20.79	54.00 ± 23.02	0.3918

Table 9

Multiple pairwise comparisons of patients of different age groups after surgery

Parameter	P value					
	(1–2)	(1–3)	(1–4)	(2–3)	(2–4)	(3–4)
Scale score, points	0.9628	0.9933	0.7152	0.9982	0.5020	0.6395
Passive flexion, degrees	0.2316	0.8445	0.3760	0.8213	1.0000	0.8616
Deficient extension, degrees	0.9972		0.8239	0.9981	0.9105	0.8616
Forearm flexor strength, points	0.8974	0.9666	0.9993	0.9982	0.9078	0.9611
Active flexion, degrees	0.9986	0.8324	0.7761	0.9117	0.7296	0.4017

Table 10

Comparison of the results of treatment depending on terms of observation (mean ± standard deviations)

Parameter	Follow-up period			p value (df = 2)
	1 (n = 7)	2 (n = 11)	3 (n = 14)	
Scale score, points	0.71 ± 0.95	1.09 ± 0.94	0.75 ± 0.86	0.5687
Passive flexion, degrees	101.43 ± 12.15	105.45 ± 13.68	104.38 ± 12.23	0.8279
Deficient extension, degrees	15.86 ± 7.54	22.30 ± 15.74	23.88 ± 11.35	0.1756
Forearm flexor strength, points	2.29 ± 1.38	3.00 ± 1.05	2.94 ± 0.93	0.4842
Active flexion, degrees	67.14 ± 26.28	69.55 ± 28.15	75.69 ± 40.24	0.4825

Table 11

Multiple pairwise comparisons of three groups of patients depending on the time after surgery

Parameter	P value		
	(1–2)	(1–3)	(2–3)
Scale score, points	0.9956	0.6658	0.5697
Passive flexion, degrees	0.8452	0.8900	0.9877
Deficient extension, degrees	0.3037	0.2327	0.9995
Forearm flexor strength, points	0.5387	0.6721	0.9381
Active flexion, degrees	0.9677	0.5723	0.6633

The statistical analysis showed no statistically significant differences between the groups that indicated that the results of PM transfer to improve elbow flexion assessed at 6 months or more did not depend on the follow-up period (Tables 10, 11).

DISCUSSION

The elbow joint is the "key" for the functional independence of the patient. The daily self-care skills requires moving the hand to the face, head, upper body that is ensured by bending the elbow up to 90 degrees. With maintained passive elbow flexion and the absence of active use of compensatory-adaptive mechanisms, they allow the patient to expand his/her functionality 16]. The age of the patient, intelligence, the dominant limb, condition of the shoulder, elbow and wrist joints, the function of the hand that is planned for reconstruction, the function of the contralateral limb, the need to use limbs, the availability of donor muscles for transplantation are important for identifying indications for an operation aimed at restoring active elbow flexion [4, 7]. PM is commonly used in patients with arthrogryposis to restore active elbow flexion, which, according to J. Chomiak, P. Dungl (2008), is the least involved in this disease with the length of muscle fibers and muscle strength being similar to those of the biceps brachii [8].

PM transfer can be performed in several ways: monopolar and bipolar, partial and complete [4–6, 8–13]. A. Van Heest et al. (1998) reported a complete bipolar transfer in patients with arthrogryposis to obtain a maximum muscle strength [4]. Theoretically the surgery could lead to weakening of the chest muscles and decreased internal rotation of the shoulder; however, patients with arthrogryposis often have intrarotational contracture in the shoulder and absence of active external rotation, and they have minimal postoperative functional disorders. An extensive access required to expose the pectoral muscle and postoperative loss of muscle strength are disadvantages of the procedure [4]. Several methods of monopolar PM transfer are described in the literature [5, 6, 8, 12]. The operation was first performed in 1917 by Schulze-Berge and consisted in transfer of the tendon of the pectoralis major muscle from the area of humerus attachment site to the belly of the biceps brachii [5].

In 1946, Clark reported a technique for partial monopolar PM transfer into the position of the biceps brachii muscle with mandatory inclusion of the medial thoracic nerve in the graft [6]. Most of the surgeries offered recently for transfer of the pectoralis major muscle are various modifications of the Clark operation [8, 10]. These techniques are technically feasible due to the anatomical features of the muscle: PM has a metameric structure and 5 different portions with the own blood supply and innervation. Based on the procedure J. Chomiak, P. Dungl developed a technique for monopolar partial PM transfer in 2008 that consisted in moving the distal part of the muscle (sternocostal, costal and abdominal portions) with the neurovascular bundle to the biceps brachii muscle with the proximal part of the muscle being intact. Preservation of the proximal portion of the PM does not lead to loss of movement in the shoulder joint, which is extremely important for patients with arthrogryposis [8]. The lateral pectoral nerve, which originates from the lateral bundle of the brachial plexus (segments C5–C6), innervates the clavicular and a portion of the sternum (the proximal part of the muscle), and the medial pectoral nerve, which originates from the medial bundle of the brachial plexus (segments C7–Th1) innervates the sternocostal, costal and abdominal portions (the distal part of the muscle) [4, 6, 8, 17, 18].

Preopereative forearm flexor strength was different in patients with arthrogryposis of different age groups and with different levels of spinal cord injury. The parameter was higher in children of primary school age than in toddlers and preschool children and was associated with the growth of children. Senior children with no active elbow flexion, who had not received surgical treatment had forearm flexors strength two times reduced compared with children of primary school age and was likely to be associated with secondary degenerative changes in muscles that occur with age due to severely limited limb function. Different strength of the forearm flexors and active elbow flexion could preoperatively develop in patients with arthrogryposis with different levels of spinal cord injury due to the anatomical features of the muscles: the biceps brachii muscle is innervated by the C5–C6 spinal cord segments, the brachial and brachioradialis – by segments C5–C8. It can be assumed that patients with C5–C6 lesions could develop active elbow flexion due to the ulnar and brachioradialis muscles, and patients with more extensive lesions had all forearm flexors involved.

Specific PM innervation and the mosaic nature of spinal cord motor neuron lesion are responsible for the fact that fibrous or fibrous-adipose tissue can be seen in the proximal part of the muscle with the muscular tissue in the distal part with the involved C5–C7 and C5–Th1 segments in patients with arthrogryposis with the exception of patients with extremely severe forms of amyoplasia and involved C5-Th1 level. The patients with arthrogryposis can benefit from partial PM transfer to restore active elbow flexion rather than from complete muscle transfer. Absence of statistically significant differences in the postoperative parameters in patients with the level of C6–C7 and C5–C7 spinal cord injury was associated with the intact segments innervating the distal portion of the PM, and patients with the C5-Th1 spinal cord injury had all segments innervating the distal portion of the PM involved that resulted in poor outcomes. Despite this, the dynamics in postoperative flexion deficiency, forearm flexor strength, active flexion after surgery was significantly better in patients with C5–Th1 segmental lesions that indicated a significant postoperative improvement in active elbow flexion.

There is a controversy regarding the optimal age of patients at the time of surgery. With our experience, active elbow flexion can be restored faster in younger patients than in schoolchildren and adolescents. A small child can acquire basic motor skills playing a game, and older children often need an explanation of how to make a particular movement. Some foreign authors would recommend operations to restore active elbow flexion in children aged 4–5 years to allow active participation of the child in the rehabilitation [4, 9]. Other researchers believe that children under the age of 5-6 years can benefit from the operations [3]. Long-term results of PM transfer for elbow flexion restoration in children with amyoplasia showed no statistically significant differences between patients of different age groups, and the choice of the optimal age for performing the operation was more likely to be associated with the surgeon preferences rather than with objective reasons. The statistical analysis of the results showed no differences between the parameters at 6 months to 7 years due to re-training of the donor muscles to perform a new function within 6 months of rehabilitation.

CONCLUSION

Pectoralis major muscle could be used for active elbow flexion restoration in patients with amyoplasia. The best results were observed in patients with C6–C7, C5–C7 segmental lesions of the spinal cord. There was no correlation between age of patient at the time of surgery and the effectiveness of operation.

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