



POSTERIOR ARTROLYSIS OF THE ELBOW, AS A METHOD OF CORRECTION EXTENSOR CONTRACTURING OF THE ELBOW IN CHILDREN WITH ARTHROGRYPOSIS

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Background. In children with arthrogryposis, a lack of elbow flexion with extensor elbow contractures limits the child's self-care.

Aim. The aims of this study were to follow and analyze treatment results after posterior arthrolysis of the elbow joint with lengthening (Z-plasty, according to the V-Y technique) or without lengthening the triceps of the shoulder in children with arthrogryposis in different age groups.

Materials and methods. Data from 109 patients with arthrogryposis with extensor contractures in the elbow joints (158 joints) who underwent posterior arthrolysis of the elbow joint to increase passive flexion in the elbow joint from 2005 to 2018 were included in this study. Clinical, and X-ray examination of patients was carried out.

Results. The children were divided into nine groups depending on their age at the time of the operation and the method of surgical correction (with or without lengthening of the triceps muscle). The follow-up period in the postoperative period in the main group of patients (67.1% of cases) was 4.5 years. Good treatment results were observed in 95.83% of children younger than 3 years who did not lengthen the triceps compared with 85.56% of children of the same age who extended the triceps tendon. The amplitude of passive movements after surgery was greatest in children younger than 1 year and was greater with lengthening ($104.00^\circ \pm 16.24^\circ$) than without lengthening ($91.38^\circ \pm 10.27^\circ$) of the triceps tendon ($p < 0.001$). However, in cases where lengthening of the triceps tendon was not performed, extension was less limited. Over 3 years, *m. triceps br.* showed satisfactory results with Z-extension and V-Y extension, increasing to 19.44% and 36.51%, respectively. Results of treatment in children older 7 than years were comparable with those of children 3–7 years old.

Conclusions. In children with arthrogryposis after posterior arthrolysis of the elbow joint, receiving a passive range of motion in the elbow joint allowed the child to use adaptive mechanisms for self-care. The results of treatment with extensor elbow contracture after posterior arthrolysis depended not on the elongation technique (V-Y or Z-plasty) but on the angle at which the triceps tendon was sewed, the patient's age at the time the operation was performed, and the postsurgery rehabilitation of the child.

Keywords: arthrogryposis; contracture; elbow; posterior capsulotomy.

ЗАДНИЙ АРТРОЛИЗ ЛОКТЕВОГО СУСТАВА КАК МЕТОД КОРРЕКЦИИ РАЗГИБАТЕЛЬНОЙ КОНТРАКТУРЫ У ДЕТЕЙ С АРТРОГРИПОЗОМ

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Обоснование. Отсутствие сгибания в локтевом суставе у детей с артрогрипозом при разгибательных контрактурах значительно ограничивает самообслуживание ребенка.

Цель — оценить результаты лечения разгибательных контрактур локтевых суставов после заднего артролиза локтевого сустава с удлинением (Z-образно, по V-Y-технике) и без удлинения трехглавой мышцы плеча у детей в разных возрастных группах.

Материалы и методы. С 2005 по 2018 г. в ФБГУ «НИДОИ им. Г.И. Турнера» Минздрава России для увеличения пассивного сгибания в локтевом суставе у 109 пациентов с артрогрипозом с разгибательными контрактурами в локтевых суставах (158 суставов) был выполнен задний артролиз. Проводили клиническое и рентгенологическое обследование пациентов.

Результаты. Все дети были разделены на девять групп в зависимости от возраста, в котором была проведена операция, и метода оперативной коррекции (с удлинением и без удлинения трехглавой мышцы плеча). Срок наблюдения большинства пациентов составил 4,5 года. У детей до 3 лет, которым не проводили удлинения трехглавой мышцы, наблюдались хорошие результаты лечения в 95,83 % случаев. У детей того же возраста, которым удлинляли сухожилие трехглавой мышцы, хорошие результаты зафиксированы в 85,56 % случаев. Амплитуда пассивных движений после операции больше всего увеличивалась у детей до 1 года, однако при удлинении сухожилия трехглавой мышцы плеча больше, чем без удлинения (без удлинения *m. triceps br.* — $91,88 \pm 10,27^\circ$, с Z-образным удлинением *m. triceps br.* — $104,00 \pm 16,24^\circ$, $p < 0,001$). Разгибание в меньшей степени было ограничено у детей, которым не выполняли удлинения трехглавой мышцы плеча. У детей старше 3 лет при Z-образном удлинении *m. triceps br.* удовлетворительные результаты зарегистрированы в 19,4 % случаев, при V-Y-удлинении *m. triceps br.* — в 36,5 %. Результаты лечения у детей старше 7 лет были сопоставимы с данными детей 3–7 лет.

Заключение. Получение пассивного объема движений в локтевом суставе у детей с артрогрипозом после заднего артролиза позволяло ребенку пользоваться приспособительными механизмами при самообслуживании. При выполнении заднего артролиза локтевого сустава с удлинением трехглавой мышцы результат лечения зависел от угла, при котором сшивали сухожилие трехглавой мышцы плеча (при угле сшивания 150° разгибание было ограничено меньше, чем при угле 100°), возраста пациента, в котором была проведена операция, и реабилитации ребенка после операции.

Ключевые слова: артрогрипоз; контрактура; локтевой сустав; задняя капсулотомия.

Background

Most patients with amyoplasia-type arthrogryposis present extensor contractures at the elbow joints. These patients present symmetrical lesions characterized by intra-rotational position of the shoulders, extensor contractures of the elbow joints, flexion contractures in the radiocarpal joints and finger joints, and adduction-flexion contracture of a finger I [1–4].

The inability to bend the arm at the elbow joint and bring the hands to the mouth significantly limits the child's ability of self-care [5–7].

Conservative treatment should be started from the first days of the affected child's life. It includes staged plaster correction of contractures of the joints of the upper extremities, massages, and physiotherapy exercises. Periarticular tissues in young children are more pliable and flexible than in older children [1, 4, 8, 9]. In children that present a rapid improvement in the range of motion of the affected joints, this is a sign of a good prognosis. If there are no positive changes within 3 months, then there are few chances of improving mobility in the future. Parents must be taught to perform exercises for the correction of contractures in the joints of the upper extremities as these exercises should be performed by the children many times during the day [1, 10].

If conservative treatment is ineffective, posterior arthrolysis of the elbow joint is performed along with elongation of the triceps muscle [11–14].

In most studies, the authors compare the range of passive movements, flexion, and extension before and after the procedure to release the elbow joint is performed [6, 12, 14], but only one study has provided a comparative analysis of these indicators according to the patients' age at which the surgical treatment was initiated [15].

The present **study aimed** to evaluate the results of the correction of extensor contractures of the elbow joints after posterior arthrolysis with elongation (Z-shaped or using the V-Y-technique) or without elongation of the triceps muscle in pediatric patients of different ages who had arthrogryposis.

Materials and methods

Between 2005 to 2018, 109 patients with arthrogryposis with extensor contractures at the elbow joints (158 joints) underwent posterior arthrolysis of the elbow joint at the Turner Scientific Research Institute for Children's Orthopedics in order to increase the passive flexion of said joint.

All patients were divided into groups by the age at which the surgery was performed and the method of surgical correction: 34 patients 0–1 years of age

Table 1

Distribution of patients in groups by age and method of posterior arthrolysis of the elbow joint

Age*	Without elongation of <i>m. triceps br.</i>	With Z-shaped elongation of <i>m. triceps br.</i>	With V-Y elongation of <i>m. triceps br.</i>
	<i>n</i> patients (<i>n</i> joints)	<i>n</i> patients (<i>n</i> joints)	<i>n</i> patients (<i>n</i> joints)
0–1 year	7 (8)	5 (10)	22 (30)
1–3 years	5 (6)	9 (16)	27 (35)
3–7 years	–	14 (24)	14 (21)
7–18 years	–	–	5 (8)

Note. *distribution by age taking into account the A.V. Mazurin classification [16].

(48 joints), 41 patients 1–3 years of age (57 joints), 28 patients 3–7 years of age (45 joints), 5 patients 7–18 years of age (8 joints) (Table 1).

The average follow-up period after surgery was 4.5 years. In 23.8% of patients, this intervention was the first step before subsequent muscle transplantation, which limited the period for evaluating the long-term outcome of the posterior arthrolysis of the elbow joint.

The clinical examination included the evaluated of indicators such as passive flexion and extension of the elbow joint, range of passive movements (before and after surgical treatment), and self-care capabilities. The range of motion in the elbow joint was determined using a pronometer.

Conventional radiographic examination was performed for patients 1 year of age or older to assess the ratio of the elbow joint, or for patients with relapse, who required repeated arthrolysis in order to prevent ossification of this area, which can preclude flexion.

The indication of posterior arthrolysis of the elbow joint was the absence or restriction of passive flexion of the elbow joint of more than 90°. Posterior release without elongation of the triceps tendon was performed in cases where passive flexion before surgery was more than 90°, but less than 125°.

The surgical technique consisted of performing an incision from the middle third of the arm along the posterior surface to the upper third of the forearm. The triceps tendon was isolated and it was not elongated in 12 patients. It was elongated in a Z-shaped elongation, with dissection from the inner portion of the ulna process in 28 patients, and it was elongated using the V-Y-elongation technique in 68 patients. The ulnar nerve was mobilized and

diverted it to the side. An elbow joint capsulotomy was performed on the posterior and lateral surfaces. Soft tissue, namely subcutaneous fat and fibrous tissue, were removed from the cubital fossa (Fig. 1). The tendon of the triceps muscle was sutured with the elbow in the flexion position at an angle of 100° for patients with a Z-elongation and at an angle of flexion of 150° for patients with a V-Y-elongation. A plaster cast was applied with the elbow joint in flexion at an angle of 90–100°.

The development of movements in the elbow joint in the articulated orthosis was started on day 2 after the V-Y elongation. Flexion to 90° and extension to preoperative values were acceptable. In the group of patients who underwent Z-elongation, rehabilitation treatment was started only 3 weeks after the surgery. For patients who did not undergo triceps muscle elongation, the development of passive flexion and extension in the elbow joint to the full extent was started on day 2 after the surgery under prolonged anesthesia of the brachial plexus

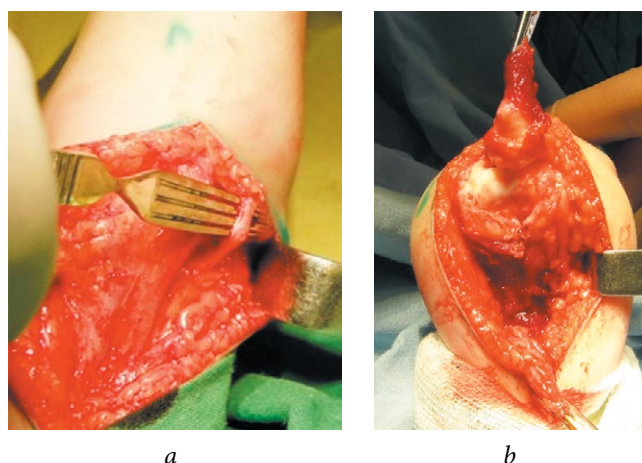


Fig. 1. Stages of posterior arthrolysis of the elbow joint: *a* — mobilization of the ulnar nerve; *b* — elongation of the tendon of the triceps muscle and capsulotomy of the elbow joint at the posterior surface

for 5–7 days. Splints were made with maximum flexion and extension of the elbow joint, and these had to be changed hourly. While the child slept, the splint was placed so that the elbow joint was at a point of maximum flexion.

For data analysis, estimation of the arithmetic mean (M) and average error of the mean (m) were calculated and the Student's t -test was used for group comparisons. Statistical significance of the differences in the mean values before and after the surgery was determined in accordance with the table of the t -test critical values. The critical level of significance in testing the statistical hypotheses was taken to be 95% ($p < 0.05$). Data were processed using the computer program Excel 2010.

Results

Posterior arthrolysis of the elbow joint with elongation and without elongation of the triceps muscle was performed in 109 patients with arthrogryposis with extensor contractures in the elbow joints (158 joints). In 60 patients, posterior arthrolysis was performed on one side, and in 49 patients, it was performed on both sides.

The average age of the patients was 3.04 ± 1.46 years (from 5 months to 17 years).

In patients under 1 year of age and from 1–3 years of age who had not undergone elongation of *m. triceps brachii*, the range of passive movements of the elbow joint ($53.5 \pm 14.8^\circ$), flexion ($121.8 \pm 12.8^\circ$) and extension ($175.4 \pm 9.1^\circ$) before surgery did not differ significantly. In patients in the group up to 1 year of age, who underwent posterior arthrolysis with elongation (Z-shaped or VY-plasty), the average values of the range of passive movements before surgery were $31 \pm 10.8^\circ$, those of flexion were $148 \pm 10.8^\circ$, and those of extension were $161.5 \pm 5.76^\circ$. These values were significantly lower than in the group without triceps tendon elongation. In the group of patients of 1–3 years of age with tendon elongation of the *m. triceps brachii*, average values were slightly higher than in patients under 1 year of age, thus, the range was $36.1 \pm 8.1^\circ$; for passive flexion, 141.6 ± 4.6 ; and for extension, $176 \pm 2.86^\circ$. In patients 3 years of age or older prior to surgical treatment, the range of motion and passive flexion in the elbow joint were within 20 – 30° , and either there was no extension restriction or it was minimal ($178.7 \pm 2.9^\circ$) (Table 2).

Table 2

Parameters of the elbow joint contracture before and after treatment in patients by group (follow-up after surgery between 1 year and 7 years)

Age, method of posterior arthrolysis	Range of motion before surgery, °	Range of motion after surgery, °	Flexion before surgery, °	Flexion after surgery, °	Extension before surgery, °	Extension after surgery, °
Up to 1 year, without elongation of <i>m. triceps br.</i> (group 1)	$57,7 \pm 3,2$	$91,8 \pm 10,2$	$123,7 \pm 13,2$	$79,3 \pm 7,33$	$177,5 \pm 5,87$	$171,2 \pm 7,33$
1–3 years, without elongation of <i>m. triceps br.</i> (group 2)	$53,3 \pm 16,6$	$84,2 \pm 12,45$	$120,0 \pm 12,45$	$82,50 \pm 4,15$	$173,3 \pm 12,4$	$163,3 \pm 12,4$
Up to 1 year, V-Y elongation of <i>m. triceps br.</i> (group 3)	$30,0 \pm 5,48$	$76,3 \pm 4,5$	$149,0 \pm 5,5$	$79,2 \pm 4,56$	$179,0 \pm 1,83$	$157,8 \pm 4,6$
1–3 years, V-Y elongation of <i>m. triceps br.</i> (group 4)	$40,1 \pm 5,72$	$76,4 \pm 4,5$	$135,7 \pm 6,5$	$78,6 \pm 4,08$	$176,0 \pm 2,9$	$153,9 \pm 3,7$
Up to 1 year, Z-elongation of <i>m. triceps br.</i> (group 5)	$33,0 \pm 16,2$	$104,0 \pm 16,2$	$147,0 \pm 16,2$	$62,0 \pm 9,2$	180	$166,0 \pm 6,9$
1–3 years, Z-elongation of <i>m. triceps br.</i> (group 6)	$32,5 \pm 10,5$	$78,1 \pm 12,1$	$147,5 \pm 10,5$	$75,3 \pm 9,1$	180	154 ± 6
3–7 years, Z-elongation of <i>m. triceps br.</i> (group 7)	$12,5 \pm 8,7$	$78,3 \pm 8,7$	$167,5 \pm 8,6$	$72,9 \pm 7,6$	180	$141,7 \pm 7,6$
3–7 years, V-Y-elongation of <i>m. triceps br.</i> (group 8)	$16,4 \pm 6,7$	$60,9 \pm 8,1$	$161,2 \pm 9,4$	$84,3 \pm 8,1$	$177,6 \pm 2,7$	$143,8 \pm 3,4$
Older than 7 years, V-Y-elongation of <i>m. triceps br.</i> (group 9)	$27,5 \pm 5,9$	$67,5 \pm 19,1$	$151,2 \pm 5,9$	$82,5 \pm 19,1$	$178,7 \pm 2,9$	$150 \pm 8,8$

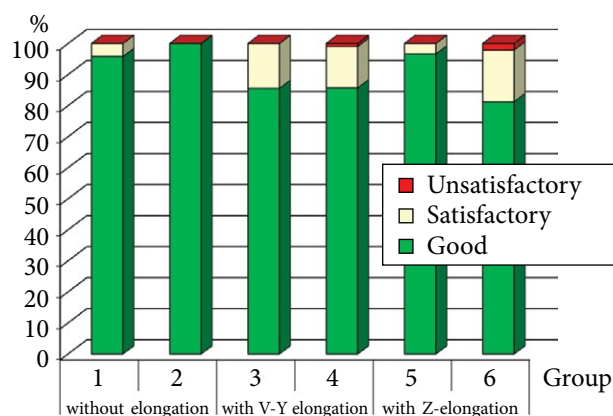


Fig. 2. Results of treatment of patients 1 year of age or less and from 1–3 years after posterior arthrolysis of the elbow joint without elongation of the triceps muscle and with V-Y and Z-elongation, $p < 0.05$

In patients under 3 years of age, regardless of whether the triceps muscle was extended or not, there was noticeable increase in flexion of the elbow joint after arthrolysis. The extension restriction, on the contrary, was more pronounced in patients who underwent triceps muscle elongation, especially in patients 3 years of age or older (see Table 2).

The results of treatment of extensor contractures by posterior arthrolysis of the elbow joints were evaluated based on the range of motion, flexion and extension of the elbow joint, and the ability to use adaptive mechanisms.

A good result was defined as flexion of the elbow joint less than 90° , a range of motion greater than 70° , and extension restriction to 30° . Additionally, the child could reach his mouth and feed himself through adaptive mechanisms.

A satisfactory result was defined as flexion at the elbow joint greater than 90° , but less than or equal to 110° and a range of motion was greater than or equal to 50° , but less than 70° , with an extension of 130° or more. The child could perform hygienic procedures, however, he could reach his mouth with the help of adaptive mechanisms only with the preserved flexion contracture of the wrist joint.

An unsatisfactory result was defined as a flexion angle of more than 110° , a range of motion of less than 50° , and an extension of less than 130° . Additionally, the child could not reach his mouth or perform hygiene procedures.

The treatment results were significantly better in patients under 3 years of age, and in two groups of three children, the tendons of the triceps were not elongated. Despite a high percentage of good results in other areas, children in which elongation was

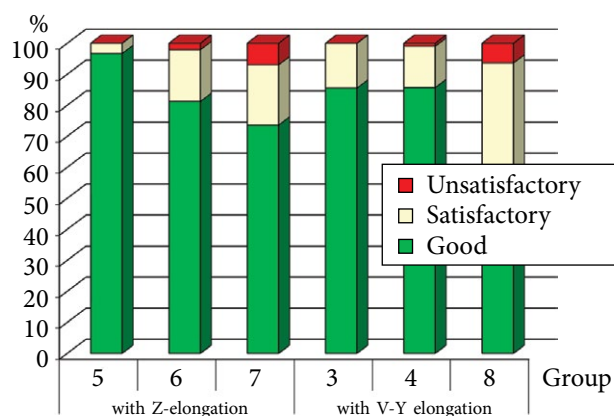


Fig. 3. Results of treatment of patients in different age groups after posterior arthrolysis of the elbow joint with elongation of the triceps muscle, $p < 0.05$

performed presented a more pronounced extension restriction at the joint.

In the groups 1 and 2 of patients who did not undergo elongation of the triceps muscle, good treatment results were registered in 95.83% and 100% of cases compared with the groups 3, 4, and 6 of patients, for which good results were seen in 85.56% of cases. The decrease in the number of good results in patients with the triceps tendon elongation (groups 3, 4, and 6) was associated with extension restriction in the postoperative period to $157.83 \pm 4.56^\circ$ compared with patients from the groups 1 and 2, in which the extension restriction was $171.25 \pm 7.33^\circ$ ($p < 0.001$). In the group of patients of 1 year of age or less, who underwent Z-elongation of the triceps muscle tendon (group 5), good results were noted in 96.67% of cases (due to the greatest increase in flexion to $62 \pm 9.28^\circ$ and a slight extension restriction after surgery up to $166 \pm 6.98^\circ$, $p < 0.001$), which is comparable with the results of treatment of patients without elongation of the triceps muscle tendon (Fig. 2).

When comparing groups of patients who underwent Z-shaped and VY-elongation of the triceps muscle, the best results were seen in patients less than 3 years of age, with Z-elongation of the triceps muscle tendon. Additionally, good results were obtained in patients 1 year of age or less in 96.67%. In those from 1–3 years of age good results were observed in 81.25% of cases. In patients 1 year of age or less with V-Y-elongation of the tendon of the triceps muscle, good results were observed in 85.56% of cases, and in those 1–3 years of good results were in 85.71% of cases. In patients 3 years of age or older with Z-elongation of the

tendon of the triceps muscle, the percentage of good results decreased. Satisfactory results were 19.44% with Z-elongation and 36.51% with V-Y-elongation of the tendon of the triceps muscle. Unsatisfactory results in these groups were registered in 6.94 and 6.35% of cases, respectively. In patients over 7 years of age, good results were achieved in 75% of cases, satisfactory results were noted in 16.67% of cases, and unsatisfactory results were in 8.33% of cases. These results did not differ much from those of patients 3–7 years of age with elongation of the triceps muscle tendon (Fig. 3).

On average, after 1.5 years, patients, who did not undergo elongation of the triceps muscle due to the limitation of flexion of more than 100°, 37.5% of cases in group 1 and 16.6% in group 2 required repeated arthrolysis of the elbow joint. In groups with elongation of the triceps muscle, 23.3% of cases in group 3; 11.4%, in group 4; 10%, in group 7; and 4.7% in group 8 required repeated arthrolysis. These were generally patients 1 year of age or less, in which movements of the elbow joints did not develop at the proper level with the short- and long-term effects of surgery. Of patients in group 1 who underwent posterior joint release without elongation of the triceps muscle, a large percentage presented relapse as many patients had a flexion greater than 125° before the surgery. In these cases, the range of motion of the elbow joint decreased more rapidly with the growth of the child. An indication for repeated arthrolysis of the elbow joint was the limitation of flexion of more than 90°, or in case the child could not bring his hand to his mouth (either by means of adaptive mechanisms or actively). The planned transposition of the body muscles into the position of the biceps with such a flexion contracture was not reasonable.

Conventional radiographic examination of the elbow joints was performed in 27 patients 1 year of age or older, with arthrogryposis with extensor contractures of the elbow joints. The delay of the ossification rate at the elbow joint was registered in 29% of cases. The ulnar and coronoid fossae were clearly distinguishable on the lateral radiograph in 87% of patients; sparseness of the bone tissue structure in the metaphysis of the humerus in the view of the ulnar and coronary fossae by the anteroposterior radiograph was traced in all patients. The ratio distortion in the humeroradial joint according to the type of anterior dislocation

of the radial head was noted in 11% of cases, while that of the posterior dislocation of the radius was seen in 3.7% of cases. The proximal end of the ulnar bone according to the anteroposterior radiograph was centered on the area of the projection location of the humeral fossae in 96.2% of cases. In 1 case, the medial subluxation of the proximal end of the ulna relative to the ulnar fossa was recorded.

In 3.8% of patients, the elbow joint had ossified after posterior arthrolysis, which impeded flexion and extension of the elbow joint. In 2 cases, after repeated arthrolysis, the ossifications recurred, and one year after the surgery the movements became oscillating, and then ankylosis appeared at an angle of 100° (Fig. 4). Only in 1.8% of patients after repeated arthrolysis of the elbow joint and removal of ossification, was it possible to obtain the range of passive movements within $56.2 \pm 3.7^\circ$ at the elbow joint.

Before surgical treatment, the strength of the biceps was 0–1 points in all patients. Active movements of the elbow joint after posterior arthrolysis of the elbow joint appeared only in 9.4% of patients. Their biceps strength increased from 0–1 to 2–3 points. This group of patients initially had good flexion and abduction at the shoulder joint (90° or more); therefore, after posterior arthrolysis of the elbow joint, due to a decrease in the gravity of the upper limb during abduction at the shoulder joint, they were able to bend the arm actively at the elbow joint. Most of the patients used adaptive mechanisms to put their hand to their mouth, namely bending on the edge of the table, bending the arm at the elbow joint with the help of the leg or the opposite arm, reaching the mouth by bending the body (Fig. 5). The strength of the biceps of these patients did not change after the surgery and amounted to 0–1 points.

Flexion contractures of the elbow joints, which required additional correction, developed in patients after elongation of the triceps muscle with age in the group of patients 1 year of age or less in 13% of cases, in patients of 1–3 years old in 18%, those aged 3–7 years old in 45 %, and in patients over 7 years old in 40% of cases.

Discussion

According to many authors, an indication for surgical correction of extensor contracture of the elbow joint is the absence or pronounced restriction

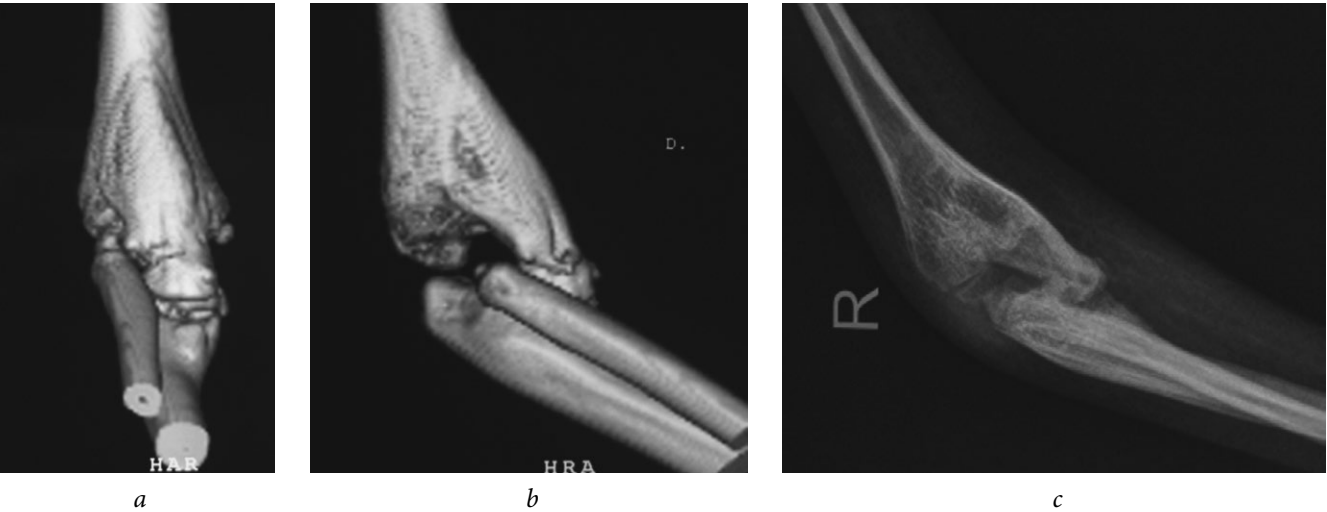


Fig. 4. Ossification of the elbow joint on the front surface of patient B., 5 years of age, after posterior arthrolysis of the elbow joint: *a* — computed tomography of the elbow joint, frontal view; *b* — computed tomography of the elbow joint, lateral view; *c* — a radiographic image of an elbow joint in a lateral view

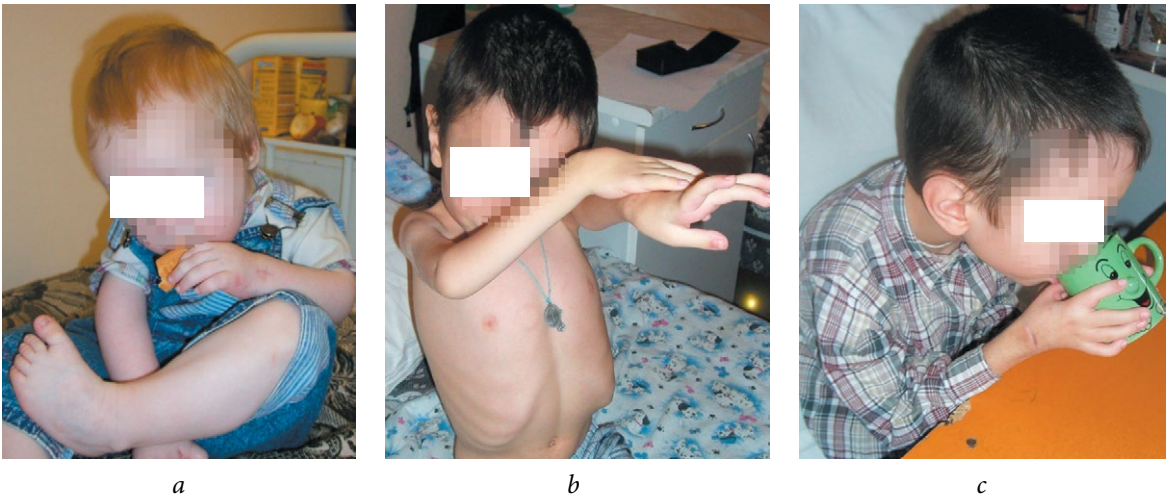


Fig. 5. Adaptive mechanisms in patients with extensor contractures of the elbow joints: *a* — flexion of the elbow joint with the help of the leg; *b* — flexion in the elbow joint with abduction in the shoulder joint and the use of the other arm; *c* — flexion of the elbow joints using the hands resting on the edge of the table

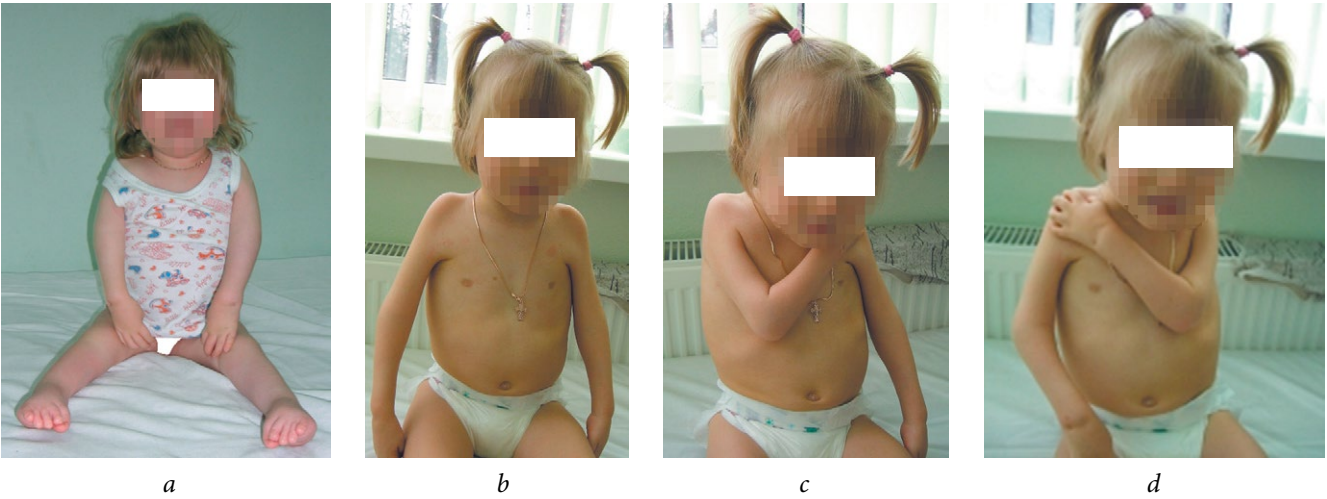


Fig. 6. Good result of treatment of the patient Ya., 4 years of age, after posterior release of the elbow joints with elongation of the triceps muscle at the age of 11 months: *a* — view before treatment (no passive flexion in the elbow joints); *b* — extension of the elbow joints after surgery; *c, d* — flexion of the elbow joints after surgical treatment

of passive flexion of the elbow joint, by which the child is incapable of reaching his mouth [6, 12–17].

M. Axt et al. (1997) evaluated movements at the elbow joints in 16 patients (22 joints) before and after the posterior release of the elbow joint. The average age of the patients was 4.4 years, and the follow-up period was 8 years. After surgery, an improvement by 39° in the range of the passive movements was noted in 17 joints compared with preoperative parameters. In five cases, unsatisfactory results were registered as the child could not put his hand to his mouth.

A. van Heest et al. (1998) analyzed similar results in 14 patients (18 joints). The average follow-up period was 5 years. The range of passive movements at the elbow joint improved from 17 to 67° after the surgery.

In the process of posterior capsulotomy of the elbow joint, some authors [6, 18–20], transposed the long head of the triceps muscle, performed transposition of the greater pectoral muscle [21, 22], or the broadest muscle of back [21, 23] in position of the biceps in order to improve the function of active flexion of the forearm.

A. van Heest et al. (2008) analyzed the results after posterior elbow joint release in 42 patients (41 joints). In this work, in addition to determining the range of motion, and flexion and extension before and after the surgery, the authors evaluated the strength of the biceps (27 patients). The range of passive movements after the surgery increased to an average of 66°. At that, despite the fact that the extension decreased by 34°, the patient's functional abilities improved. Most of the patients after this surgery could bring their hand to the mouth by means of adaptive mechanisms. The appearance of active movements in the elbow joint due to an increase in the strength of the biceps from 0 to 3–4 points was noted in only two out of 27 cases.

C. Richard and R. Ramirez (2019) conducted a retrospective analysis of 13 patients (18 joints) and estimated the range of motion, flexion, and extension of the elbow joint before and after surgery in different age groups, but the number of patients in the groups was often minimal (3 patients (5 joints) under 2 years of age, 7 patients (10 joints) aged 2–3 years, 3 patients older than 3 years (3 joints)). The range of passive movements before surgery was the smallest in patients under 2 years (16°) and increased with age (33.5° from 2 to 3 years, and up to 45° in a group of patients older than

3 years). The best results were obtained in a group of patients under 2 years of age. The range of their motion increased from 16 to 88.2°. In the group of patients 2–3 years of age or older, the difference in the range of motion before and after the surgery amounted to 28.5°. In patients 3 years of age or older, the initial range of motion in the elbow joint averaged 45° and increased after surgery only by 9°. Based on this, the authors believed that posterior arthrolysis of the elbow joint without combination with muscle transplantation should be performed in patients 2 years of age or less.

According to our cases, posterior arthrolysis of the elbow joint without elongation of the triceps muscle should be performed only for patients aged 0 to 3 years, whose flexion before surgery was no more than 125°; otherwise, as the child grew, the achieved range of motion in the elbow joint quickly decreased and repeated arthrolysis was required. The range of passive movements after surgery increased most in patients under 1 year of age (Fig. 6) with posterior arthrolysis without elongation of the tendon of the triceps muscle to $91.38 \pm 10.27^\circ$ and with Z-elongation of the tendon of the triceps muscle to $104 \pm 16.24^\circ$ ($p < 0.001$). In patients 1–3 years of age, the range of motion after surgical treatment was significantly less; without elongation of the triceps muscle it was $84.17 \pm 12.45^\circ$ ($p < 0.05$); with V-Y-elongation it was $76.43 \pm 4.49^\circ$ ($p < 0.01$); and with Z-shaped elongation it was $78.13 \pm 12.07^\circ$ ($p < 0.05$). The range of motion depended on an increase in the angle of flexion and extension restriction after surgery; therefore, when performing posterior arthrolysis with elongation of the *m. triceps brachii* tendon, the angle at which the tendon was sutured was important. Extension of the elbow joint was less restricted in patients under 1 year of age, who did not undergo elongation of the triceps muscle, compared with patients 1–3 years of age or patients of the same age, but who underwent posterior release with elongation of the triceps muscle (see Table 2).

In patients who underwent elongation of the triceps muscle, the range of passive movements, flexion and extension of the elbow joint after surgery decreased with the age of the child and increased duration after the surgery. These indicators in patients 7 years of age and older were comparable with the results of treatment of patients 3 years of age (see Table 2).

Active flexion in the elbow joint after posterior arthrolysis appeared in only 9.4% of cases. In order to bring their hand to their mouth, patients used adaptive mechanisms, which corresponded with data reported by other authors [14, 15]. The choice of the mechanism of adaptive movements depended on the safety of movements at adjacent joints, at the opposite upper limb, as well as at the joints of the lower extremities.

Conclusion

Posterior arthrolysis of the elbow joint should be performed in patients with extensor contractures of the elbow joints before these patients reach 1 year of age so that the best result can be achieved. If flexion in the elbow joint is less than 125°, capsulotomy of the elbow joint without elongation of the triceps muscle can be performed. This leads to less restriction of elongation at the elbow joint with age. When performing posterior arthrolysis of the elbow joint with elongation of the triceps muscle, the treatment result depends on the angle at which the tendon of the triceps muscle is sutured, on the patient's age when the surgery is performed, and also on the timing of the onset of rehabilitation treatment during the postoperative period. With age, pediatric patients who underwent posterior arthrolysis of the elbow joint with elongation of the tendon of the triceps muscle noted progression of flexion contracture. Achievement of a passive range of motion in the elbow joint allowed the child to use adaptive mechanisms in for self-care and self-feeding. These were planned to undergo muscle transplantation subsequently to obtain active flexion at the elbow joint.

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All patients and/or their legal representatives signed voluntarily informed consent to participate in the study, perform surgical intervention, and publish personal data.

Contribution of the authors

E.V. Petrova performed collection and analysis of the data, prepared the text, and created the article design.

O.E. Agranovich collected and analyzed the data obtained, edited the text of the article.

S.I. Trofimova, E.A. Kochenova collected the material and processed it.

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