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Original Study Article

On the treatment of high unilateral congenital hip dislocation in older children: Minimizing the inequality of limb length

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BACKGROUND: Treatment of high congenital hip dislocation in older children remains controversial in terms of the choice of the method of reducing the femoral head to the level of the acetabulum. In most cases, significant shortening of the hip is performed to eliminate dislocation, which leads to secondary deformities.

AIM: This study aimed to evaluate the results of treatment of high hip dislocation in older children, in which pre-reduction skeletal traction and economical shortening of the femoral segment are rationally combined to lower the femoral head.

MATERIALS AND METHODS: From 2011 to 2021, we observed 13 patients aged 5–13 years with grade 4 high unilateral congenital hip dislocation according to the international Tonnis classification.

RESULTS: The treatment results were traced for 1–9 years. When assessing hip joint function according to McKay criteria, excellent and good results were obtained in 84.6% of the patients. X-ray evaluation by Severin also included 84.6% in groups 1 and 2. Signs of avascular necrosis of the femoral head according to the criteria of Kalamchi and MacEwen were detected in four patients (group 1, $n = 2$; group 2, $n = 1$; group 3, $n = 1$). The difference in the length of the n/limbs in eight patients was 1.5 cm on average, and in the remaining children, a clinically insignificant asymmetry was observed in the length of the n/limbs, i.e., 0.5–0.7 cm.

CONCLUSIONS: The choice of the method of surgical correction of high hip dislocation largely depends on the age of the child. In children aged >5 years, with a significant displacement of the femoral head and limb shortening, a combination of reduction methods is rational, i.e., use of preoperative skeletal traction with economical shortening of the femoral segment, open reduction, and correction of the acetabulum. The optimal combination of the distraction method and surgical correction makes it possible to achieve successful reduction and a good functional result.

Keywords: high congenital hip dislocation; older children; adolescents; lower limb length inequality; limb shortening; pre-reduction traction; shortening osteotomy.

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Оригинальное исследование

К вопросу о лечении высокого одностороннего врожденного вывиха бедра у детей старшего возраста: минимизация неравенства длины конечностей

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Обоснование. Лечение высокого врожденного вывиха бедра у детей старшего возраста остается спорным в отношении выбора метода низведения головки бедренной кости до уровня вертлужной впадины. В большинстве случаев для устранения вывиха прибегают к значительному укорочению бедренной кости, что приводит к развитию вторичных деформаций.

Цель — обмен опытом и оценка результатов лечения высокого врожденного вывиха бедра у детей старшего возраста с использованием двухэтапного метода, при котором для низведения головки бедренной кости выполняют рациональное укорочение бедренного сегмента с последующей дистракцией конечности в аппарате.

Материалы и методы. Под нашим наблюдением с 2011 по 2021 г. находились 13 пациентов в возрасте от 5 до 13 лет с высоким односторонним врожденным вывихом бедра IV степени по международной классификации Tonnis grade.

Результаты. Результаты лечения прослежены в сроки от 1 до 9 лет. При оценке функции тазобедренного сустава по критериям McKay отличные и хорошие результаты получены у 84,6 % пациентов. При рентгенологической оценке по Severin к I и ко II группе отнесены также 84,6 %. Признаки аваскулярного некроза головки бедренной кости по критериям Kalamchi/MacEwen отмечены у 4 пациентов (I группа — 2, II группа — 1, III группа — 1). Разница длины нижних конечностей у 8 пациентов в среднем составила 1,5 см (1,2–1,8 см), у остальных детей зарегистрирована клинически незначимая разница — около 0,5–0,7 см.

Заключение. Выбор метода оперативной коррекции высокого вывиха бедра во многом зависит от возраста ребенка. У детей старше 5 лет при значительном смещении головки бедренной кости и укорочении конечности рационально сочетание методов низведения, а именно использование предоперационной скелетной тракции с экономным укорочением бедренного сегмента. Оптимальное совмещение дистракционного метода с укорочением сегмента при высоких запущенных вывихах бедра позволяет достичь успешного вправления и хорошего функционального результата.

Ключевые слова: высокий врожденный вывих бедра; дети старшего возраста; подростки; неравенство длины нижних конечностей; укорочение конечности; прередукционная тракция; укорачивающая остеотомия.

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ЭКО•ВЕКТОР

BACKGROUND

High congenital hip dislocation is a severe form of hip dysplasia. The treatment of high dislocation in children older than 5 years is quite a difficult task for a pediatric orthopedist. Under the influence of the load on the limb and in the absence of bone support for the femoral head, the proximal femur is displaced cranially into the iliac region. Owing to the lack of contact between the articular surfaces, the head and cavity grow and develop without close interaction, which further exacerbates the impairment of the spatial orientation of the proximal femur and underdevelopment of the acetabular roof. The longer the hip dislocation exists, the more the constriction of muscles and neurovascular formations increases, and the soft tissues become rigid and difficult to stretch, which complicates the restoration of the relationship between the femoral head and the cavity. The choice of approach depends directly on the age, previous treatment, and degree of hip dysplasia.

Most orthopedists suggested that in older pediatric patients, the elimination of dislocation should be accompanied by simultaneous surgical correction, including reduction and correction of the femoral segment and acetabulum. However, many controversial and unresolved issues remain, for example, there is no unequivocal opinion on the method of achieving the most rational and less traumatic reduction of the femoral head to the level of the acetabulum in the case of high dislocation.

Some orthopedists believe that the femoral segment must be shortened for the reduction of the femoral head when excessive force is required to reposition the hip joint. The length of femur shortening depends on the degree of the head displacement and is determined by the amount of overlap between the osteotomized fragments of the femur after reduction; in some cases, resection can be 4–5 cm or longer [1–3].

Traction is another technique of reducing the femoral head to the acetabulum in high dislocation. Traction is performed in various ways. Some orthopedists use a distraction apparatus for this [4, 5], whereas others consider it sufficient to perform longitudinal traction of the limb on the plane with the use of weights [6]. For the treatment of high hip dislocation, several authors combine preoperative traction and shortening of the femoral segment [7, 8].

Following a literature review, extremely few studies have focused on the treatment of high hip dislocation in older children. Moreover, no approach has been established for the treatment of this pathology, and the choice of the method of reducing the femoral head is the subject of discussion and debate.

The work aimed to exchange experience and evaluate the treatment results of high congenital hip dislocation in older children using a two-stage method, in which rational shortening of the femoral segment is performed to reduce the femoral head, followed by limb distraction in the apparatus.

MATERIALS AND METHODS

From 2011 to 2021, 13 patients aged 5–13 years who has high unilateral congenital hip dislocation were monitored.

According to the international Tönnis grade classification [9], all patients had grade IV dislocation, where the femoral head was located above the upper lateral edge of the cavity. However, the height of the femoral head displacement varied significantly, and the head cranial displacement was more significant in older children than in those aged 5–7 years (Table 1). Thus, the height of the displacement of the femoral head from the cavity and the Russian classification of Volkov, Ter-Egiazarov, and Yukina [10] must be considered. According to this classification, depending on the location of the femoral head, high dislocation is divided into supra-acetabular (the head is located at the level of the iliac body) and iliac (the head is located at the level of the iliac wing). In our patients, supra-acetabular dislocation was found in eight hip joints and iliac dislocation in five cases.

All patients underwent a clinical and radiological examination with standard functional tests, radiographs, and computed tomography and functional radiographs with a traction test. The degree of soft tissue stiffness and the possibility of femoral head reduction due to traction were assessed using an X-ray with a traction test. During the traction test, the proximal femur was simultaneously displaced by 1.0–1.5 cm caudally in comparison with its position on the radiograph without traction. Then, when planning for the surgical intervention, the required angle of correction of the caput–collum–diaphyseal angle was calculated. Most patients required 20°–25° femoral neck varization. When the femoral neck is varized by 20°–25°, the head moves around the circumference [11]. Thus, when the caput–collum–diaphyseal angle is varized by 25°, the femoral head is displaced down by 1.2 cm, thereby approaching the acetabulum.

Moreover, the amount of the required shortening of the femoral segment was calculated. The amount of discontinuity in the Shenton line was deducted by the value

Table 1. Degree of femoral head displacement depending on age

Parameter	Age, years		
	5–7	8–10	11–13
Quantity	6	2	5
Shenton's line discontinuity, cm M ± SD	3.83 ± 0.98	4.5 ± 0.7	5.8 ± 0.45

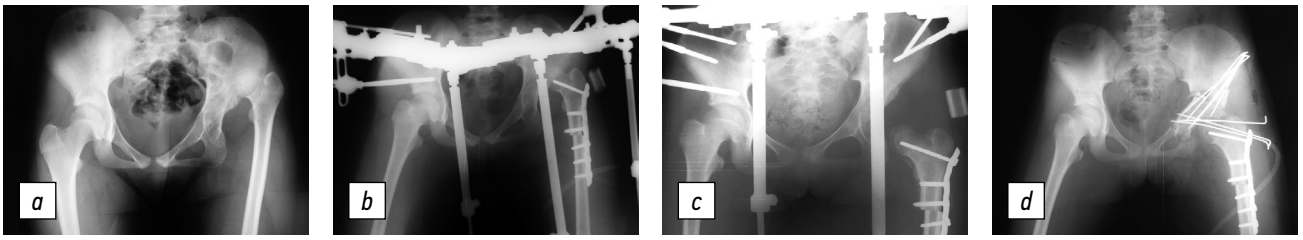

Fig. 1. Radiographs of patient T., 13 years old, with high congenital dislocation of the left hip: *a,* before the treatment of iliac dislocation, the head of the left femur is located at the iliac wing level, with discontinuity of the Shenton line of 6 cm, acetabular index of 60°, angle of vertical inclination of the cavity 68°, caput–collum–diaphyseal angle of 125°, and anteversion of the femoral neck of 50°; *b,* stage 1 of surgical treatment included shortening detorsion osteotomy of the femur with the imposition of a distraction apparatus on the pelvis and left thigh. The resected bone fragment (2.5 cm) is located in the subcutaneous tissue in the acetabular zone; *c,* X-ray image 2 weeks after the distraction start. The head of the left femur was reduced to the level of the lower edge of the acetabulum; *d,* in stage 2 of surgical treatment, the distraction apparatus was dismantled, and open reduction of the femoral head into the acetabulum and triple osteotomy of the pelvis on the left with transposition of the acetabulum were performed

of possible head reduction obtained during the traction test and by the value of downward displacement of the head during the caput–collum–diaphyseal angle varization. For example, if the femoral head is displaced cranially with the Shenton line discontinuity of 5 cm, when the femoral neck is varized by 25°, a reduction of 1.2 cm will be added, and muscle relaxation during gradual traction was also considered, which will slightly increase the reduction rate due to traction (on average, no more than 0.5 cm was added). As a result, the size of the femoral segment resection was 2.0 cm. Thus, in eight patients, the resection of the femur was 13.8 ± 2.7 mm (10–18 mm), and in five pediatric patients, it was 32.5 ± 5.0 mm (20–35 mm).

All patients underwent surgery, which consisted of two stages. At stage 1, a rational shortening detorsion–varus osteotomy of the femur was performed with the imposition of a distraction apparatus, which was used to eliminate the residual displacement of the femoral head in the postoperative period. At stage 2, when the femoral head was opposed to the acetabulum, open reduction and pelvic osteotomy with correction of the acetabulum were performed (Fig. 1).

Fig. 2. Patient's appearance at the stage of treatment with the MKC wire-rod distraction apparatus

Detorsion or detorsion–varus osteotomy of the femur was the standard. The iliopsoas muscle was dissected compulsorily from the place of attachment to the lesser trochanter. Femoral shortening was performed by resecting the distal bone fragment. The bone fragments were fixed with an L-shaped or reconstructive plate. The resected fragment of the femur was placed in a pocket in the subcutaneous tissue in the projection of the body of the ilium, and it was saved for subsequent use in stage 2 of surgical treatment. Then, a distraction system was applied to the pelvis and thigh. The distraction apparatus consisted of a module of the MKC apparatus [12], located on the pelvic bones, and a ring of the Ilizarov apparatus installed in the lower third of the thigh (Fig. 2).

In the postoperative period, usually starting from day three after the surgery, distraction in the apparatus was started. The degree of distraction was 3–5 mm per day. The design of the device enabled the activity of the child using crutches with support on the contralateral limb. At the distraction stage, physiotherapy was performed using paraffin and ozocerite and magnetic therapy. The duration of the distraction period averaged 10–14 days. During this time, the femoral head was reduced to the level of the acetabulum, which was recorded on the radiograph. Then, stage 2 of surgical treatment was started.

At stage 2, the apparatus was dismantled, and open reduction was performed with the reconstruction of the acetabulum. For open reduction, an anterior longitudinal approach from the anterosuperior iliac spine down, 7–8 cm long, was used. Pelvic osteotomy was performed from the same approach. To access the joint cavity, a Z-shaped capsulotomy was performed. The fibrous fat pad was removed from the cavity, and the round ligament was dissected. In some older children (10–13 years) with iliac dislocation, the round ligament of the head was absent; it most probably ruptured during head migration and restructured into a fibrous fat pad in the bottom of the cavity. The transverse ligament of the cavity, which prevented sufficient immersion

of the head, was dissected. The deformed limbus, which was thickened, was turned inside or hung down, covering a part of the entrance to the cavity. It was transversely incised in 2–3 places and bent outward using a levator. The constriction of the capsule in the inferomedial part of the joint always prevented reduction, although the iliopsoas muscle was already dissected from the lesser trochanter at stage 1, which in turn influences the formation of this constriction. We can assume that the prolonged existence of this bending of the joint capsule due to muscle tension led to irreversible changes in this zone, and the stricture of the capsule persisted even after the muscle dissection. This stricture was dissected under strict control and protection of the neurovascular formations in this zone.

After the cavity was released, the head was reduced. No modeling resections of the femoral head were performed; the head was freely placed in the cavity. Even in cases where the femoral head slightly exceeded the cavity dimensions, the underdevelopment of the anterior and posterior margins, presence of a free lower part of the cavity, and absence of constriction of the para-articular tissues due to pre-reduction traction enabled positioning the head in place without effort. The femoral head was fixed in the cavity with two wires. The joint capsule was sutured with the displacement of the leaflets, and the excess flap of the capsule was sutured to create a duplicate of the anterior part of the capsule. The stretched capsular sac in the supra-acetabular zone was also tightly sutured.

Then, the acetabulum was corrected. Pediatric patients aged <7 years underwent Salter pelvic osteotomy. Children aged ⩾8 years underwent triple pelvic osteotomy with the transposition of the entire acetabulum. Salter pelvic osteotomy was performed according to the classical technique of the author [13], where an autograft, previously extracted from the subcutaneous tissue, was placed in the area of osteotomized fragments of the ilium after tilting the cavity roof. Triple pelvic osteotomy was performed using two approaches. Osteotomy of the ischial and pubic bones was performed through the medial adductor approach. In the projection of the adductor muscles, the long and slender muscles were preliminarily dissected for more convenient access to the ischium. From the same approach, an osteotomy of the pubic bone was performed. Iliac osteotomy was performed from the anterior approach, from which open reduction was performed. After the transsection of all three bones, the fragment with the acetabulum was turned outward and downward until the femoral head overlapped. The transposed fragments of the ilium were fixed with threaded wires, and an autograft was placed in the diastasis zone in advance. Additional fixation was performed in a coxite plaster cast with the lower limb in moderate abduction.

The duration of immobilization was 5–6 weeks. Subsequently, the wires fixing the femoral head in the cavity were removed, and restorative treatment was prescribed. Walking with a load on the operated lower limb was allowed after 4–5 months, after the consolidation of the osteotomy of the femur and ilium. The fixing hardware was removed 8–9 months after the surgical treatment, generally 4–5 months after weight bearing on the limb was allowed.

The treatment results of patients were followed up for 1–9 (mean follow-up time, 6.2 years). The function was assessed according to the McKay classification [14]. The Severin system was used for the radiological assessment of hip joint stability [15]. Postoperative indicators of the head shape as a sign of avascular necrosis were considered in accordance with the Kalamchi/MacEwen classification [16].

Statistical analysis was performed using the IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY, USA). Quantitative data were analyzed using descriptive statistics methods after preliminary testing for normal distribution using the Shapiro–Wilk test. Paired *t*-test for related populations was used to evaluate the before–after results with two comparisons. Arithmetic means (M), standard deviation (±SD), and confidence interval (95% CI) were calculated. The result was considered significant at $p < 0.05$.

RESULTS

In all 13 hip joints, Tönnis grade IV dislocation was recorded before treatment. After treatment, according to McKay's criteria for assessing hip function (Table 2), function was assessed as excellent in four hip joints, good in seven hip joints, and satisfactory in two hip joints. According to Table 2, four patients fully recovered their hip joint function (Fig. 3).

Table 2. Functional outcome of treatment according to McKay's criteria

Score	Criteria	Number of patients
Excellent	Stable, painless hip, no lameness, negative Trendelenburg sign, and full range of motion	4
Good	Stable, painless hip, mild lameness, negative Trendelenburg sign, functionally sufficient range of joint motion	7
Satisfactory	Stable, painless hip, lameness, positive Trendelenburg sign, restriction of joint movement	2
Poor	Unstable or tender hip, or both, positive Trendelenburg sign	–

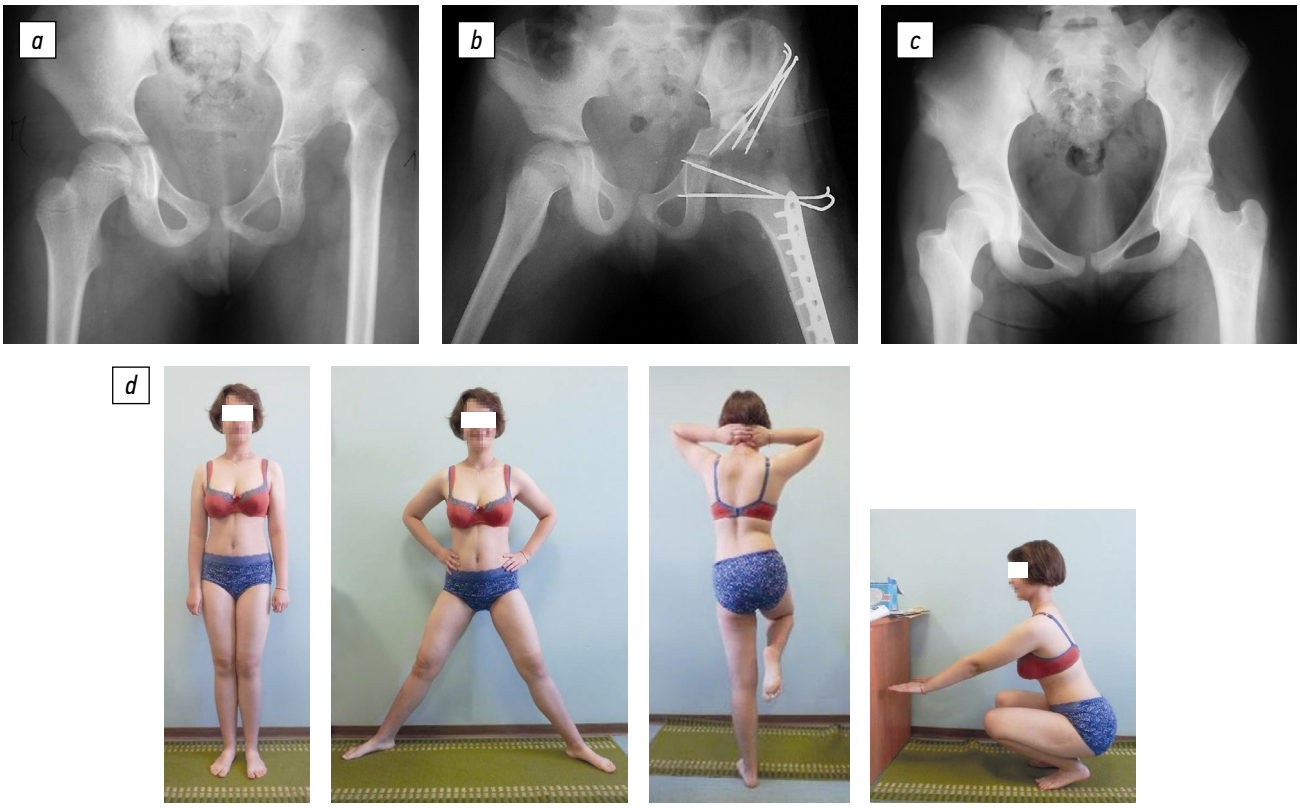

Fig. 3. Patient S. with high congenital dislocation of the left femur at the stages of treatment: *a,* radiograph at the age of 7 years before treatment revealed iliac dislocation of the left femur, the femoral head is located at the level of the iliac wing, and the discontinuity of the Shenton line is 5 cm; *b,* radiograph immediately after the staged treatment with the restoration of ratios in the left hip joint; *c*, X-ray result of treatment at the age of 15 years: grade IA according to the Severin classification; *d,* functional result of treatment (age 15 years): group "excellent" according to McKay's criteria

In seven pediatric patients, some limitations in joint rotational movements were noted, which practically did not affect limb function, and the lower limb lengths differed by 0.5–1.5 cm, causing mild lameness (Fig. 4). In two patients, limited hip joint movements were reflected as a limitation of flexion and rotational abduction. The Trendelenburg symptom was positive, and lameness occurred due to a limb-length discrepancy of 2 cm (Fig. 5).

X-ray assessment of the hip joints before and after treatment (Table 3) revealed that all indicators characterizing the hip joint development underwent statistically significant ($p < 0.05$) changes in comparison with their values before surgery. This indicates the restoration of the joint ratios and its stability.

Table 4 presents the results of assessing the anatomical and radiological ratios in the joint after treatment according to the Severin classification.

As shown in Table 4, 11 patients achieved a stable reduction with the restoration of the normal parameters of the bone covering of the femoral head with the roof of the acetabulum (Fig. 3*c*). Four of these patients had a slight deformity of the femoral head with the preservation of the normative index of joint stability (Wiberg angle) (Fig. 4*f*). Two patients had residual signs of hip dysplasia with a decrease in the Wiberg angle (<20°) (Fig. 5*d*). In general, excellent and good development of the hip joint was achieved in 11 of 13 (84.6%) patients.

Signs of the development of aseptic necrosis of the femoral head were detected in four patients (Table 5).

According to the Kalamchi/MacEwen classification, head deformity corresponding to grade I was diagnosed in two patients, grade II in one patient, and grade III in one patient. All patients were treated at the age >8 years and had a very high location of the femoral head (iliac dislocation). In two patients with grade 1 according to the Kalamchi/MacEwen classification, aseptic necrosis was manifested as structural post-repositional changes, which subsequently regressed, persistent residual deformity, and spherical femoral head. Clinically and radiologically, 4–5 years after the treatment, the hip joint function was satisfactory, there was no lameness or pain syndrome, a slight limb-length discrepancy (up to 2 cm) was compensated by a lining for shoes, and the femoral head remained spherical and was congruent to the cavity. These patients were at grade II according to Severin and McKay's (Fig. 4).

A complicated course with the development of aseptic necrosis of the femoral head (grade III according to the Kalamchi/MacEwen classification) in a patient with high iliac hip dislocation, who was treated at the age of 12 years, is presented in Fig. 5. Three years after treatment, a deformity

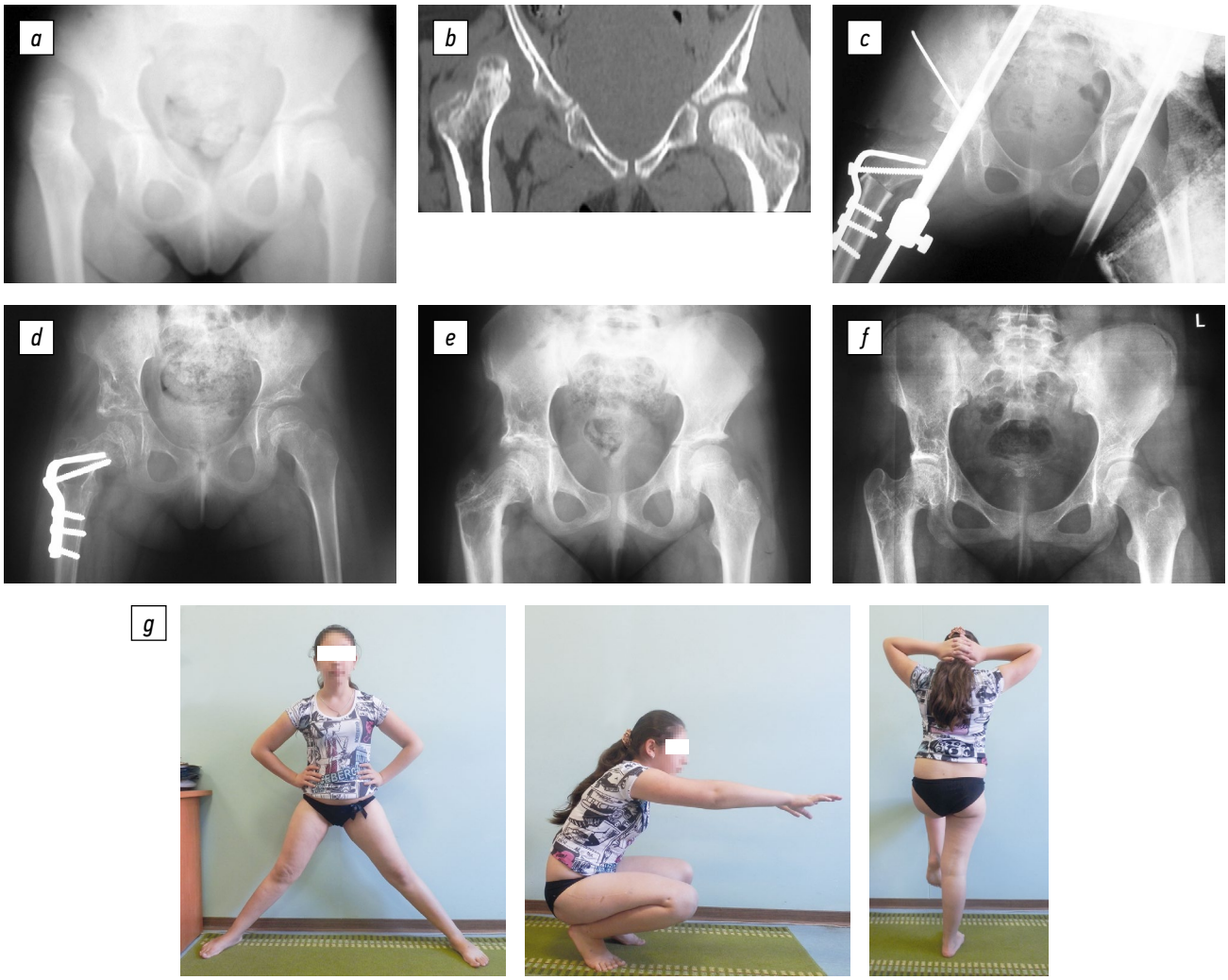

Fig. 4. Patient T. with high congenital dislocation of the right hip, grade I according to the Kalamchi/MacEwen classification: *a, b,* radiographs at the age of 8 years, showing iliac dislocation of the head of the right femur and discontinuity of the Shenton line 6 cm; *c,* radiograph at the stage of surgical treatment, immediately after the femoral head reduction, with fixation in the distraction apparatus; *d,* radiograph 6 months after reduction, the femoral head is centered in the cavity, its structure is heterogeneous, and its sphericity is preserved; *e,* radiograph 2 years after treatment (age 10 years); *f,* radiograph 5 years after treatment (age 13 years), grade I according to the Kalamchi/MacEwen classification, grade II according to the Severin classification; *g,* functional result of treatment (age 13 years), "good" group according to McKay's criteria

of the proximal femur with a heterogeneous structure was detected; however, with the preservation of the femoral head sphericity, its centering in the cavity did not cause instability. Clinically, the range of motion in the hip joint was reduced, and the limb function was moderately limited.

DISCUSSION

Treatment for congenital hip dislocation aimed at achieving a stable and concentric reduction of the head with good subsequent development of the joint. The treatment complexity and its outcome are inversely proportional to the patient's age when reduction is performed. Dislocations of the hip, detected or not treated at the age of >5 years, are very severe, and sometimes insurmountable difficulties arise in their treatment. Given the high risk of complications and uncertainty, many surgeons refuse to eliminate such dislocations and, at best, refer patients to highly specialized hospitals and sometimes recommend doing nothing. Thus, adolescents aged 11–13 years with high hip dislocation, which was diagnosed at the age of 3–4 years, but was never treated, still seek medical help. If patients with bilateral hip dislocation are compensated for a long time and their joints function well (indications for their treatment after the age of 4–5 years are still being discussed), then unilateral hip dislocation leads to significant limb dysfunction, asymmetric and incorrect formation of the entire musculoskeletal system, rapid decompensation, and development of pain syndrome. In this regard, the issue of eliminating unilateral hip dislocation, even in pediatric patients of senior school age, should always be resolved positively, unless there are any serious contraindications for surgical treatment.

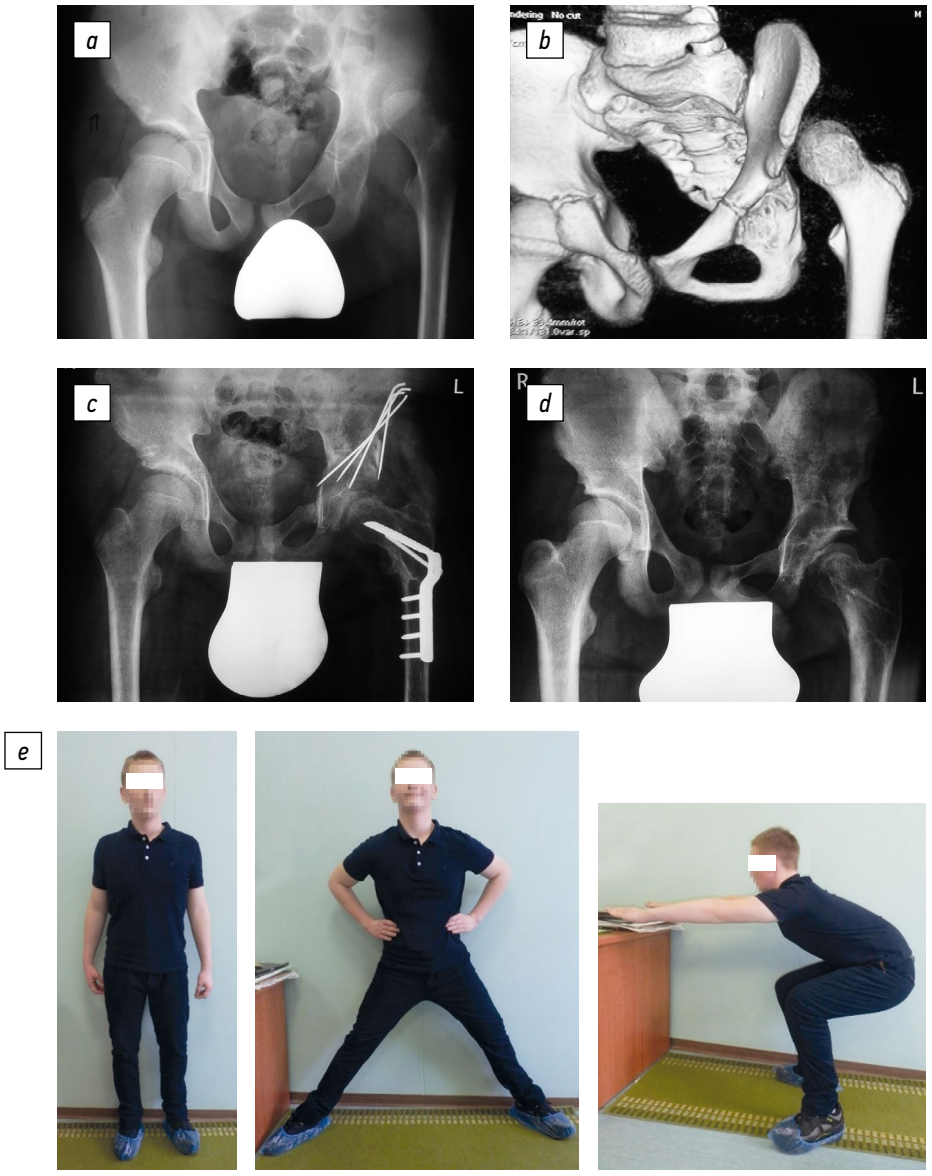

Fig. 5. Patient K. with high congenital dislocation of the left hip, grade III according to the Kalamchi/MacEwen classification: *a*, *b*, radiographs at the age of 12 years showing iliac dislocation of the left hip and discontinuity of the Shenton line of 6 cm; *c*, radiograph 2 months after surgical treatment; *d*, radiograph 3 years after treatment (age 15 years), showing aseptic necrosis of the femoral head with preservation of its sphericity, short femoral neck, grade III according to the Kalamchi/MacEwen classification and grade III according to the Severin classification; *e*, functional result of treatment (age 15 years); "satisfactory" group according to McKay's criteria

Table 3. X-ray indicators of the anatomical structure and stability of the hip joint before and after treatment

Indicators	Follow-up stages				*p*
	Before treatment		After treatment		
	M ± SD	95% CI	M ± SD	95% CI	
CCDA, deg.	153.21 ± 5.56	149.95–156.67	121.23 ± 3.19	119.3–123.16	
Anteversion, deg.	50 ± 4.48	44.27–55.73	15.92 ± 3.57	13.77–18.08	
Sharpe angle, deg.	63.77 ± 3	61.95–65.58	35.08 ± 4.23	32.52–37.63	<0.001*
AI, deg.	42.69 ± 5.41	39.43–45.96	13.08 ± 3.33	11.07–15.09	
Wiberg angle, deg.	Negative	–	37.0 ± 3.92	30.5–42.4	

* Changes in indicators are statistically significant ($p < 0.05$).
Note. AI, acetabular index; CCDA, caput–collum–diaphyseal angle.

Table 4. Radiological result of treatment according to the Severin classification

Score	Grade	Criteria	Number of patients
Excellent	IA	Stable hip joint, Wiberg angle >19° (age 6–13 years); Wiberg angle >25° (age >14 years)	4
	IB	Stable hip joint, Wiberg angle 15–19° (age 6–13 years); Wiberg angle 20–25° (age >14 years))	3
Good	II	Stable hip joint, but with moderate deformity of the head, femoral neck, and acetabulum. X-ray parameters are the same as in grade I	4
Satisfactory	III	Hip joint dysplasia, but without subluxation of the femoral head; Wiberg angle <20° (age >14 years)	2
Poor	IV	Subluxation	–
	V	Femoral head in the false acetabulum	–
	VI	Reluxation	–

Table 5. Results of assessing the development of the femoral head aseptic necrosis after treatment, according to the Kalamchi/MacEwen classification

Grade	Criteria	Results
I	Heterogeneous structure of the femoral head and expansion of the femoral neck 1 year after reduction, increased radiographic density with subsequent fragmentation. Residual deformity, but with the restoration of head sphericity	2
II	Damage to the lateral side of the growth plate (the main characteristic of this group) and development of subcapital *coxa valga* with a tendency to deficient acetabular coverage	1
III	Damage to the central part of the growth plate and short neck of the femur without varus or valgus deformity. Relative overgrowth of the greater trochanter and limb-length discrepancy	1
IV	Injury to the entire femoral head and physis. Femoral head deformity with varus, flattening, and *coxa magna*, greater trochanter overgrowth, limb-length discrepancy, and subsequent early arthritis	–

The methods of surgical treatment used to eliminate dislocation are well recognized and known, such as detorsion–varus osteotomy of the femur and open reduction and osteotomy of the pelvis. In most cases, surgeons follow the pathway of the so-called least resistance to obtain a good result in the shortest possible time. Moreover, complete reconstruction of the joint is performed, and to achieve reduction, the femur is shortened by the entire displacement of its head. In a few international and Russian publications on the treatment of high dislocation in older children, the authors, describing the technique, point to femoral shortening by the amount of displacement of osteotomized femoral fragments, that is, from 1 to 2.5 cm [17]. Subsequently, this shortening in no way affected the result, and the limb-length discrepancy did not bother patients and their parents. When analyzing these studies and the magnitude of femoral shortening, the magnitude of cranial displacement of the femoral head did not exceed 2–3 cm. Most articles use the international Tönnis classification, according to which the dislocation is divided into four degrees. This classification considers the anatomical location of the femoral head relative to the cavity, but it does consider the magnitude of the absolute displacement of the femoral head, which can vary significantly. Thus, in our patients, hip dislocation corresponded to Tönnis grade IV. In some patients, the head displacement was 3 cm, whereas it was 6 cm in others, and this is important when choosing the treatment approach. Unfortunately, we did not reveal an international classification that could consider the displacement height or magnitude of discontinuity of the Shenton line; therefore, in this study, we used the Tönnis classification (according to international standards) when describing a group of patients, but supplemented it with the division of patients into subgroups taking into account the height of the femoral head displacement according to the classification of Russian orthopedists [10].

The analysis of the most widely used method of femoral head reduction by shortening the femoral segment was

continued, and results showed that with large displacements of the head, sometimes reaching 6 cm, shortening by the entire amount is irrational for the following reasons. First, with a large resection of the segment, the points of attachment of the muscles approach significantly, which subsequently causes a decrease in their strength and instability of adjacent joints. Second, a large difference in limb lengths will require further compensation by lengthening this segment, which is impractical and is not always possible in the case of hip joint dysplasia. Considering all of the above, we have developed an approach for eliminating high hip dislocation in older children by sparing pre-reduction traction with simultaneous economical shortening of the femoral segment. Dividing the total amount of displacement into two components enables the preservation of the limb-length as much as possible and reduces the probability of avascular complications.

Short-term fixation in the distraction apparatus in the physiological position of the limb does not have any adverse effect, unlike traction in the abduction in the hip joint (frog leg position). Pediatric patients in the apparatus are verticalized, move using crutches, and adapt gradually to future immobilization in a plaster cast. In addition, a gradual distraction of para-articular tissues in the physiological position of the limb increases the metabolic activity of endothelial cells of blood capillaries, which has a positive effect on the blood supply to the joint structures and reduces the risk of aseptic necrosis of the femoral head [18, 19].

The presented method of treating high hip dislocation in older children obtained excellent and good results in 11 of 13 cases (84.6% of patients). Aseptic necrosis of the femoral head was diagnosed in 4 of 13 patients (30.7%); however, in two of them (grade I according to the Kalamchi/MacEwen criteria), structural postrepositional changes regressed, and residual deformity of the proximal femur in the form of femoral neck shortening did not impair the sphericity and congruence of the joint. Clinically and radiologically, 5 years after treatment, the patients retained good function and the hip joint had continuous development. When assessing the results according to Severin's and McKay's classifications, they were assigned to grade II (good result).

Comparing our results with those of other studies is difficult because only a few studies have evaluated the treatment of high hip dislocations in older children over the past decade. Only a few authors evaluated the results of the correction. Ning et al. [20] analyzed children in the older age group with Tönnis grade degree IV dislocation (over 6–8 years) and obtained good results according to Severin in 64.6% of cases. El-Tayeby et al. [2] achieved good results in pediatric patients older aged >8 years in 78% of cases. Forlin et al. [21] achieved good results in 70% of cases, whereas poor outcomes were recorded in patients aged >7 years at the time of surgery. Tilyakov et al. obtained good results in 36.4% of patients with high hip dislocation [22]. Teplenky et al. used a distraction apparatus and achieved good results in 77% of patients aged up to 8 years [5].

According to the literature, aseptic necrosis of the femoral head after treatment of high hip dislocation in is diagnosed in 19.8%–69% of pediatric patients aged >3 years. Thus, when evaluating the treatment results of late hip dislocation, Angliss et al. [23] registered manifestations of Kalamchi/MacEwen grade I aseptic necrosis in the first 5 years after treatment in 69% of patients. As the children grew, 49% had growth plate disorders and deformity corresponding to Kalamchi/MacEwen type II, and only 18% of patients had no manifestations of aseptic necrosis. Castañeda et al. [24] reported aseptic necrosis in 19.8% of pediatric patients aged ⩾3 years. Charki M. Tazi [25] detected aseptic necrosis in 20% of children aged >1 year, whereas the incidence of aseptic necrosis was significantly higher in patients aged >3 years. Ning et al. [20] diagnosed aseptic necrosis in 57% of children aged over 6–8 years with Tönnis grade IV dislocation.

Our treatment results and the incidence of aseptic necrosis in literature data were not comparable because all studies analyzed surgical outcomes in pediatric patients with hip dislocation of the so-called walking start age [20, 24, 26]. When evaluating the results of such interventions, the younger the patients, the better the result of the correction, and the best age for simultaneous surgery for hip dislocation is up to 8 years [27]; however, the treatment of dislocation in adolescence is a debatable issue. In our opinion, high unilateral hip dislocation should be treated even in adolescence. The use of a combined treatment method, namely, preoperative skeletal traction combined with economical shortening of the femoral segment, is one of the best options for older patients with a high displacement of the femoral head. When using traction, in addition to the head reduction (main task), contracted soft tissues are gradually stretched, thereby avoiding post-reposition pressor effects on the femoral head and improving the ability of tissues to tolerate hypoxia. Economical femoral shortening minimizes the loss of limb-length and improves functional and cosmetic results by restoring the symmetrical length of the lower limbs at the end of treatment.

CONCLUSION

The treatment results of high hip dislocation in older children using the presented technique are comparable with the findings of other authors. Moreover, compared with other studies, this method was used in older patients. We believe that this treatment method can be considered one of the options for achieving successful reduction and a good functional result in the treatment of complex and severe high hip dislocation in older children and adolescents.

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