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SURGICAL TREATMENT OF CHILDREN WITH HIP DYSPLASIA COMPLICATED WITH AVASCULAR NECROSIS OF THE FEMORAL HEAD

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Introduction. Avascular necrosis of the femoral head complicates the surgical treatment of hip dysplasia and aggravates the prognosis.

Aim. We studied the immediate and medium-term results of reconstructive treatment in 18 children with hip dysplasia complicated by avascular femoral head necrosis, which developed after closed repositioning of a congenitally dislocated femur.

Material and methods. Average age at the time of operation was 4.2 ± 0.2 years. The patients were divided into two groups. Group 1 included 12 children with hip subluxation who underwent extra-articular reconstructions on articular components, spinal tunneling of the neck and head, and hardware unloading of the joint and group 2 included six patients with hip dislocation in whom an additional open reduction was performed. Functional results were estimated using D'Aubigne-Postel classification, whereas X-ray results were evaluated using Kruczynski classification.

Results. Duration of observation was 3–7 years (average, 4.2 ± 0.3 years). Functional results were good (15–18 points) in nine joints in group 1, satisfactory (12–14 points) in three joints in group 1 and five in group 2, and unsatisfactory (11 points) in one joint in group 2. X-ray results were good in six joints in group 1, satisfactory in six joints in group 1 and five in group 2, and unsatisfactory in one joint in group 2.

Conclusions. Extra-articular reconstructive and stimulatory interventions combined with hardware decompression helps improve the shape and structure of the femoral head, and formation of congruent articular surfaces in children with subluxation of the thigh complicated by avascular necrosis.

Keywords: avascular necrosis of the femoral head; hip dislocation; hip dysplasia.

ХИРУРГИЧЕСКОЕ ЛЕЧЕНИЕ ДЕТЕЙ С ДИСПЛАЗИЕЙ ТАЗОБЕДРЕННОГО СУСТАВА, ОСЛОЖНЕННОЙ АСЕПТИЧЕСКИМ НЕКРОЗОМ ГОЛОВКИ БЕДРЕННОЙ КОСТИ

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Введение. Асептический некроз головки бедра усложняет хирургическое лечение дисплазии тазобедренного сустава и усугубляет прогноз.

Цель исследования заключалась в изучении ближайших и среднесрочных результатов реконструктивного лечения у детей дисплазии тазобедренного сустава, осложненной асептическим некрозом головки бедренной кости.

Материал и методы. Проанализированы результаты лечения 18 детей с асептическим некрозом головки бедренной кости, развившимся после закрытой репозиции врожденного вывиха бедра. Средний возраст пациентов на момент выполнения оперативного вмешательства составил 4,2 ± 0,2 года.

Результаты лечения проанализированы в срок от 3 до 7 лет (средний срок — 4,2 ± 0,3 года). В 12 наблюдениях при подвывихе бедра выполнены внесуставные реконструктивные вмешательства на суставных компонентах, спицевая туннелизация шейки и головки, аппаратная разгрузка сочленения. В шести наблюдениях при вы-

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вихе бедра дополнительно производили открытое вправление. Пациенты были распределены на две группы. В первую группу вошли 12 детей с подвывихом бедра. Вторую группу составили 6 пациентов с вывихом бедра. Функциональные результаты оценивали по D'Aubigne-Postel. Первая группа: хороший (15–18 баллов) результат — 9 суставов, удовлетворительный (12–14 баллов) результат — 3 сустава; вторая группа: удовлетворительный (12–14 баллов) результат — 5 суставов, неудовлетворительный (11 баллов) результат — 1 сустав. Рентгенологические результаты оценивали по Kruczynski. Первая группа: хороший результат — 6 суставов, удовлетворительный результат — 6 суставов; вторая группа: удовлетворительный результат — 5 суставов, неудовлетворительный результат — 1 сустав.

Выводы. Представленная технология внесуставных реконструктивных и стимуляционных вмешательств в сочетании с аппаратной декомпрессией обеспечивает условия для улучшения формы и структуры головки бедра, формирования конгруэнтных суставных поверхностей у детей с подвывихом бедра, осложненным асептическим некрозом.

Ключевые слова: асептический некроз головки бедренной кости; врожденный вывих бедра; дисплазия тазобедренного сустава.

Introduction

Perthes disease is recognized as a serious complication in the treatment of congenital hip dysplasia [1, 2]. Perthes can lead to head deformity, changes in the proximal femoral bone geometry (PFB), and an impaired articular ratio that create conditions for early development and rapid progression of coxarthrosis [3, 4]. This pathology is considered iatrogenic and does not occur in an untreated joint [5]. The frequency of Perthes disease with a closed reduction of hip dislocation varies from 10% to 60% [6–8]. If a complication has developed in the set joint, therapies are aimed at stimulating reparative processes, preventing the development of coxarthrosis, and subsequent surgical correction of secondary biomechanical disorders in the joint [1]. The situation becomes more complicated in the case of a combination of degenerative disorders with residual instability and decentration of the femoral head. Most medical specialists prefer an active surgical approach [1, 5, 9]. Conversely, aggressive treatment may increase the risk of an adverse outcome [3, 10, 11].

This study aimed to analyze the immediate and medium-term outcomes of reconstructive treatment in pediatric patients with hip dysplasia, complicated by Perthes disease.

Material and methods

We analyzed treatment outcomes for 18 pediatric patients (15 females/3 males) with Perthes disease developed after a closed reduction of congenital hip dislocation. The average age of patients on the day of surgery was 4.2 ± 0.2 years (range from 2 to 6 years). Treatments were performed from 2009 to 2014, with the time between dislocation reduction and surgery ranging from 18 to 48 months.

The inclusion criteria included: signs of aseptic necrosis in accordance with the Salter criteria (delayed ossification, fragmentation of the pineal gland, thickening of the neck for more than a year after the reduction of dislocation) [12], dysplastic acetabulum, and decentration of the femoral head with a follow-up period of not less than 3 years. The degree of decentration of the femoral head and the severity of dystrophic changes in the pineal gland were assessed according to the Tönnis criteria [13]. Joints with degrees II and III of dislocation were recorded (degree II represents the femoral head displaced outward from the Perkins line, but lower than the upper edge of the cavity; degree III represents the femoral head at the level of the upper edge of the cavity). The Tönnis classification of head necrosis demonstrated that degree II represents a distortion of the shape and structure of the pineal gland, and marginal defects; degree III represents a complete fragmentation and flattening of the pineal gland; and degree IV includes lesions of the pineal gland, metaphysis, and growth zone.

The exclusion criteria included a period after repositioning of less than a year, the consequences of surgical reduction of the dislocation, and a centered position of the femoral head in the cavity.

The treatment outcomes were analyzed from 3 to 7 years after surgery (average period was 4.2 ± 0.3 years). Functional outcomes were assessed according to the d'Aubigné and Postel hip score, and radiographic parameters were evaluated according to Kruczynski [7].

Radiographs of the hip joint in the antero-posterior projection were studied. Radiographs completed before the surgery, one year after hardware treatment, and the final control examination were assessed with the acetabulum indices and PFB radiographic parameters. The acetabulum indices included the acetabular index (*AI*), the acetabular coefficient (*AK*, $N \geq 250$), the acetabulum sphericity index (*SI*, $N = 110–125°$) [14], and the index of thickening of the bottom of acetabulum (*ITBA*, $N = 14–15, 5°$) [14]. The PFB parameters included neck-shaft angle (*NSA*) and lateralization of the greater trochanter (*LT* is the ratio of the distance from the center of the head to the vertical line drawn through the apex of the greater trochanter to the diameter of the head; $N = 1.15–1.25$). Indicators of femoral head centration in the cavity include discontinuity of the Shenton's arc, cranial displacement (*SLI*), the lateral displacement angle (*LDA* angle formed by a vertical line drawn through the tear-shaped figure and the line tangential to the lower medial edge of the neck; $N = 20–25°$) [7], and the acetabulum – head index (*AHI*) [7].

For radiographs performed one year after removal of the apparatus and the last examination, additional PFB parameters were recorded, namely the articular and trochanter distance (*ATD*), the epiphyseal index (ratio of pineal gland height to pineal gland width), and the articular surface index (ratio of pineal gland height to double radius of the head) [15]. As proposed by Lauritzen–Meyer, the shape of the head was evaluated [15]. For this evaluation, the epiphyseal coefficient (*EQ*), the coefficient of the articular surface (*JSQ*), and the radius coefficient (*RQ*) were determined using the ratio of indices of the affected and intact joints. The indicators of normal sphericity were identified by $EQ > 60$, $JSQ > 80$, and $RQ < 115$. The indicators of pathological sphericity were identified by $40 < EQ < 60$, $60 < JSQ < 80$, and $115 < RQ < 130$. The indicators of asphericity were identified by $EQ < 40$, $JSQ < 60$, and $RQ > 130$.

The congruence of the articular surfaces was evaluated according to the Coleman criteria (type 1: spherical congruent, type 2: spherical noncongruent, type 3: aspherical congruent, and type 4: aspherical noncongruent) [16].

Radiological exams were performed using certified equipment authorized by the Ministry of Health of the Russian Federation (FS No. 2006/527). The study was conducted in accordance with the ethical standards of the Helsinki Declaration of the World Medical Association, as amended by the Ministry of Health of the Russian Federation. All the patients provided informed consent for performed studies and all data was de-identified.

Two methods of treatment were applied for patients recruited for this study. For twelve patients with hip subluxation, a closed restoration of the articular ratio was performed with extra-articular reconstructive interventions on the hip joint components, tunneling of the neck and head, and hardware unloading of the joint. Hardware decompression included support distraction in the joint area of 1 mm per week for the entire treatment period (50–60 days). For acetabular dysplasia correction, a complete transverse osteotomy of the iliac bone was used, followed by lateral and anterior transposition of the acetabulum. In all cases, both articular components were corrected.

Intervention on the femoral component provided for intertrochanteric detorsion (12 joints) or varus-detorsion osteotomy (6 joints). The anteversion angle was reduced to 15°, and the neck-shaft angle was reduced to 110°. Surgical treatment aimed at the restoration of articular ratio with provisional conditions for the formation of congruent articular surfaces. In view of this, the main focus of femur surgery was to stabilize the ratios described above (with dislocation, stabilization, and additional decompression of the articulation). Therefore, only those elements that hindered the centration of the femoral head in the cavity (excessive anteversion, *coxa valga*) were removed during femur surgery without correcting varus deformity of the neck. In our opinion, the restoration of normal PFB indices in preschool pediatric patients with ischemic lesions of the head is impractical due to the high probability of recurrence of deformity. Moreover, it is well known that the optimal age for restoring PFB geometry is between the ages of 9 and 11 years [17].

Tunneling of the neck and head necessitated creating 5–6 channels into the head of the femur with either a wire or perforator from the subtrochanteric region. A total of 2–3 ml of the suspension obtained during the puncture of the bone marrow cavity (the iliac bone was punctured in the analyzed group) was injected into the channels [18]. This procedure was performed twice, first during implantation and again during the removal of hardware. For six hip dislocation cases, an open reduction was performed with the above procedures. For the remaining cases, hip osteotomy was supplemented with elements of shortening to provide additional decompression of the articulation.

Results

Patients were distributed into two groups, based on anatomical features. Group 1 consisted of 12 pediatric patients (mean age was 4.2 ± 0.3 years) presenting with hip subluxation. Group 2 consisted of 6 patients (mean age was 4.2 ± 0.4 years) presenting with hip dislocation.

Group 1 had clinical signs of pathology that included lameness and relative shortening of the limb by 1–1.5 cm. Out of twelve cases in Group 1, eleven patients had a moderate pain syndrome (4.6 ± 0.2 points) and eight patients had an abduction limited to 110–115° (4.8 ± 0.3 points).

In all joints, a degree II level of dislocation was diagnosed. The distribution of joints according to the degree of necrosis showed two joints with degree II, eight joints with degree III, and two joints with the degree IV. The average *AI* value for Group 1 was 35.6 ± 0.7°.

Group 2 had clinical signs of pathology that also included lameness but with a relative shortening of the limb by 2–3.5 cm. All patients in Group 2 had a moderate pain syndrome (4.3 ± 0.2 points). A flexion restriction of 90–95° and an abduction of 95–100° was indicated in two Group 2 cases. The remaining cases in Group 2 demonstrated an abduction limitation of 105° (3.7 ± 0.2 point).

Across patients in Group 2, 2 joints had a dislocation degree II and 4 joints had a dislocation degree III. Joints classified with a degree II of dislocation were attributed to dislocations due to the interposition of soft tissues and the inability to restore the articular ratio by changing the spatial position of the hip.

For Group 2, the degree of necrosis revealed 2 joints with a degree II, 2 joints with a degree III, and 2 joints with a degree IV. The average *AI* value for Group 2 was 36.8 ± 0.7°.

The rehabilitation period for Group 1 was 8.6 ± 0.4 months, with an improvement in gait observed in 11 patients (5.4 ± 0.2 points). In six cases, a normal walking gait and full restoration of limb support function was achieved. However, a moderate limitation of movement persisted in four cases. The average mobility index in Group 1 was 5.6 ± 0.2 points. In most cases, pain was absent or was insignificant (5.8 ± 0.1 points). Full compensation shortening was achieved in all patients. The distribution of functional results in the Group 1, in accordance with the criteria of d'Aubigné and Postel, revealed good (15–18 points) outcomes in 9 joints and satisfactory (12–14 points) outcomes in 3 joints.

The rehabilitation period for Group 2 was 13.2 ± 0.3 months. In five cases, a mild pain syndrome was recorded (5.2 ± 0.2 points). The amplitude of movement was limited by various degrees in all joints (4.0 ± 0.4 points). In one case, a decrease in mobility was noted when compared with the baseline. The average gait index was 4.2 ± 0.3 points. Relative shortening within 1.5 cm was recorded in three cases. The functional results in Group 2 patients were satisfactory (12–14 points) in 5 joints and poor (11 points) in 1 joint.

X-ray data in both groups a year after surgery revealed a significant improvement for all parameters characterizing the acetabulum ($p < 0.001$). At follow-up, average values of *AI* and *SI* reached normal levels in Group 1 patients. Normal *AK* values were only observed in patients with baseline necrosis degrees of II and III. In pediatric patients with a degree IV of dystrophic disorders, this parameter was reduced. *ITBA* exceeded normal values regardless of the initial state of the femoral head.

In Group 1, the average values of *AI* and *SI* corresponded to the norm, while only *AI* corresponded to the norm in Group 2. The remaining parameters that characterize the shape and depth of the cavity were significantly worse in Group 2 when compared to Group 1 ($p < 0.01$). In one case with an initial degree III of necrosis, normal indices of the cavity sphericity index and *AK* were recorded (Table 1).

In both groups one year after surgery, all parameters defining the degree of head centration in the cavity improved significantly. One year after treatment, *LDA* and *AHI* values were improved in Group 2 ($p < 0.01$) but later changed in different directions. In Group 1, regardless of the severity of the initial dystrophic disorder, an improvement and normalization of the above parameters was observed ($p < 0.01$). In Group 2, the average *LDA* and *AHI* values deteriorated and reached the borderline values. More pronounced negative changes were recorded in three pediatric patients with degrees IV (2 joints) and III of necrosis. The average indices of cranial displacement (*SLI*) achieved as a result of surgery did not change significantly in follow-up for both groups (see Table 1).

A gradual deterioration of the *ATD* index was found when reviewing the condition of the proximal femur in Group 1 patients with a necrosis degree of II and III. For two patients with a necrosis degree of IV, only a decrease in *LT* was observed. The articular and trochanter distance did not change significantly. In Group 2, the deterioration between the head and the trochanter was more pronounced. A decrease in *ATD* and *LT* was registered only in patients with a necrosis degree of III and IV. The average *NSA* within the first year after surgery decreased in both groups. At follow-up, this parameter did not change significantly (see Table 1).

One year after treatment, the head sphericity indices in Group 1 were significantly improved when compared with Group 2 ($p < 0.001$), but still did not correspond to the norm. At follow-up, an improvement of the sphericity coefficients was noted in Group 1, with the average *EQ* and *RQ* approaching borderline values. In two patients with an initial necrosis degree II and in one patient with a necrosis degree III, the head shape sphericity was in the normal range. In two patients with necrosis degrees of III and IV, an aspherical head

Table 1

X-ray observations in 18 patients with Perthes disease

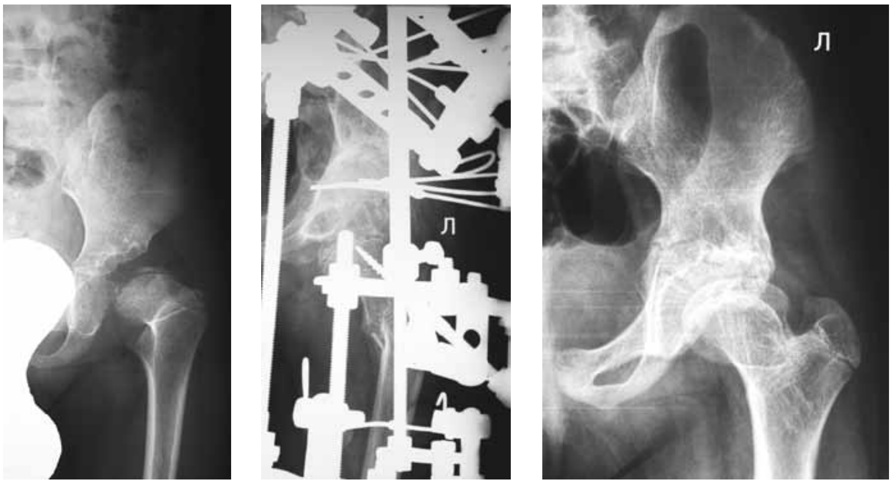
Parameter	Group 1 ($n = 12$)			Group 2 ($n = 6$)		
	Follow-up period			Follow-up period		
	Prior to surgery	One year after surgery	Long-term outcomes	Prior to surgery	One year after surgery	Long-term outcomes
AI, °	35.6 ± 0.7	11 ± 1.7 $p < 0.001$	12 ± 1.6	36.8 ± 0.7	13.2 ± 0.5 $p < 0.001$	12.6 ± 0.8
AK	172.7 ± 10.9	219.8 ± 14.8 $p < 0.001$	236 ± 11.5* $p < 0.001$	154 ± 10.4	200 ± 5.6 $p < 0.001$	223.7 ± 7.9* $p < 0.01$
SI, °	144.3 ± 2.5	130.8 ± 2.7 $p < 0.01$	123.4 ± 2.5* $p < 0.05$	142.5 ± 3.4	133 ± 1.3 $p < 0.05$	129 ± 2.3
ITBA, °	29.1 ± 0.9	25.5 ± 1 $p < 0.01$	23.8 ± 1.2	30.3 ± 0.9	25.3 ± 0.9 $p < 0.01$	24 ± 0.9
NSA, °	125 ± 4	112 ± 2	112.8 ± 1.7	126 ± 6.6	112.8 ± 1.8	111 ± 3.7
ATD, mm	14.1 ± 1.5	10.2 ± 1.3	9 ± 1.03	13.3 ± 2.5	11 ± 0.5	8.2 ± 0.8
LT/ratio	0.95 ± 0.05	0.97 ± 0.02	0.9 ± 0.02	0.92 ± 0.05	0.9 ± 0.05	0.78 ± 0.05
EQ		0.58 ± 0.03	0.6 ± 0.03* $p < 0.05$		0.44 ± 0.02	0.48 ± 0.02* $p < 0.05$
JSQ		0.56 ± 0.05	0.62 ± 0.04* $p < 0.01$		0.43 ± 0.04	0.46 ± 0.05
RQ		129.8 ± 6	119.4 ± 4.1* $p < 0.05$		139.8 ± 7.3	130.5 ± 5.9* $p < 0.05$
SLI, mm	10.9 ± 1.4	1.8 ± 0.5 $p < 0.001$	1.2 ± 0.5	23.7 ± 2.7	2 ± 1.8 $p < 0.001$	1.6 ± 2.6
LDA, °	34.3 ± 1.9	24 ± 1* $p < 0.001$	21.8 ± 1.1	48.7 ± 3.8	20.5 ± 1.1* $p < 0.001$	26 ± 0.9
AHI	0.58 ± 0.02	0.85 ± 0.02* $p < 0.001$	0.92 ± 0.03	0.18 ± 0.04	0.94 ± 0.01* $p < 0.001$	0.81 ± 0.01

Note. AI — acetabular index; *AK* — acetabular coefficient; *SI* — acetabulum sphericity index; *ITBA* — index of thickening of the bottom of acetabulum; *NSA* — neck-shaft angle; *ATD* — articular and trochanter distance; *LT* — ratio of the distance from the center of the head to the vertical line; *EQ* — epiphyseal coefficient; *JSQ* — articular surface ratio; *RQ* — radius coefficient; *SLI* — cranial displacement; *LDA* — angle formed by the vertical line drawn through the tear-shaped figure and the line tangential to the lower medial edge of the neck; *AHI* — the acetabulum – head index.

Table 2

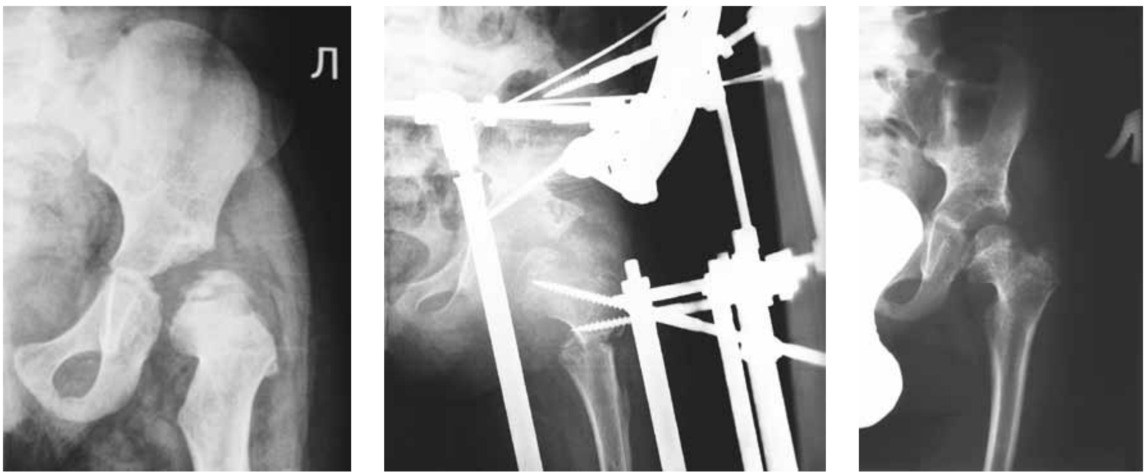
Radiographic treatment results for 18 patients, considering the initial degree of the femoral head necrosis

Group (head necrosis degree)	Articular surface congruence by Coleman			Treatment outcomes byKruczynski		
	I	III	IV	good	satisfactory	poor
1 (II)	2			2		
1 (III)	2	6		3	5	
1 (IV)		1	1	1	1	
2 (II)		2			2	
2 (III)		2			2	
2 (IV)		1	1		1	1
Total	4	12	2	6	11	1



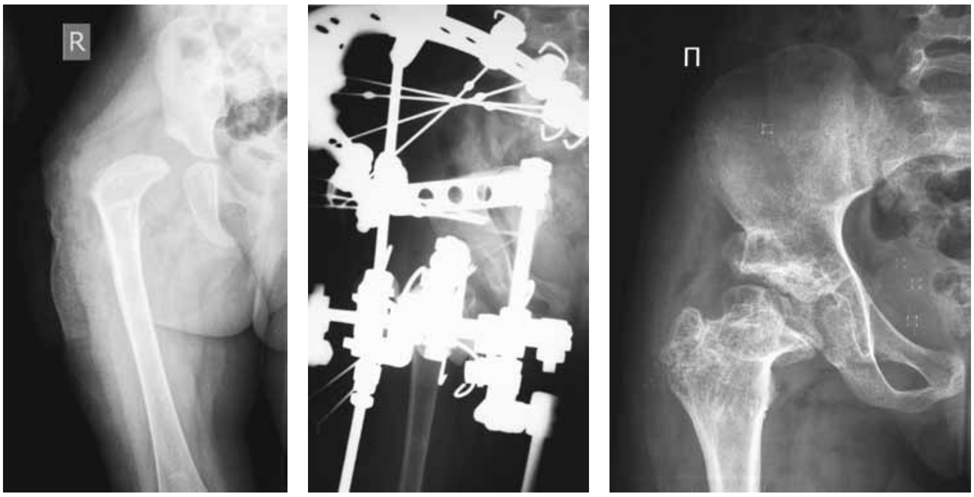
a *b* *c*

Fig. 1. Patient M., 5 years old, with a diagnosis of subluxation of the left hip, degree II of dislocation, and degree IV Perthes disease: *a* — frontal radiograph of the hip joint before treatment; *b* — frontal radiograph of the hip joint during treatment (after tunneling of the femoral neck and head, extra-articular reconstruction of the pelvic and femoral components of the joint, hardware decompression of the joint); *c* — frontal radiograph of the hip joint 5 years after treatment



a *b* *c*

Fig. 2. Patient D., 4 years old, with a diagnosis of subluxation of the left hip, degree II of dislocation, and degree II Perthes disease: *a* — frontal radiograph of the hip joint before treatment; *b* — frontal of the hip joint during treatment (after tunneling of the femoral neck and head, extra-articular reconstruction of the pelvic and femoral components of the joint, and hardware decompression of the joint); *c* — frontal radiograph of the hip joint 3 years after treatment



a *b* *c*

Fig. 3. Patient F., 4 years old, with a diagnosis of congenital dislocation of the right hip, degree III of dislocation, and degree IV Perthes disease: *a* — frontal radiograph of the hip joint before treatment; *b* — frontal radiograph of the hip joint during treatment (after performing an open reduction of the dislocation, shortening correcting osteotomy of the hip, osteotomy of the iliac bone, tunneling of the femoral neck and head, hardware decompression of the articulation); *c* — frontal radiograph of the hip joint 4 years after treatment

was diagnosed. In the remaining seven cases, the condition of the head was assigned pathological sphericity.

For Group 2, the parameters of the femoral head did not significantly change one year after surgery (see Table 1). In two cases with baseline necrosis degrees of II and III, the head shape presented as pathologically spherical. For the remaining cases, the head sphericity distortion (asphericity) was indicated.

When assessing the articular surface congruence by Coleman, only three types of articular surfaces were noted, with type II (spherical non-congruent surfaces) being absent. As shown in Table 2, types I and III prevailed. Spherical congruent articular surfaces were formed only after extra-articular surgeries with initial head necrosis degrees of II and III.

There were no cases among the joints examined that presented with an excellent outcome. Good results were noted only when performing extra-articular interventions (see Table 2). In general, positive outcomes were observed in 94% (Figs. 1–3).

Discussion

Great importance is attached to the prevention of Perthes disease in hip dysplasia [1], since treatment options for necrosis are limited. Known surgical interventions, including epiphysiodesis, greater trochanter transposition, centering osteotomies of the articular components, are aimed at correcting secondary changes in the anatomy of the proximal femur and articular ratio disorders [10, 19, 20]. It is currently not possible to restore normal function to the damaged proximal epiphysial plate of the hip, to restore local microcirculation in the femoral head until irreversible changes occur [1].

As a rule, aseptic necrosis develops in the set joint. The resulting ischemic deformity of the proximal femur can cause secondary acetabular dysplasia and subluxation of the femur. However, in some cases, the development of dystrophic disorders in the head is possible when reposition is not achieved. For this situation, there is no consensus on the treatment approach, with opposing viewpoints on the nature of therapeutic measures. Expectant tactics reduce the risk of further progression of dystrophic disorders. A decentered head position leads to conditions for deformity progression, which in turn contributes to the deterioration of the articular ratio [3, 21, 22]. A worst-case scenario is brought about by a pronounced formation and irreversible deformities of the articular components, which significantly impede subsequent reconstructive interventions [20]. However, immediate surgical treatment provides restoration conditions for the femoral head and the formation of congruent articular surfaces [3, 5, 9, 21]. Known reconstructive surgeries are considered aggressive and are accompanied by increased intra-articular pressure as well as contribute to a rapid progression of dystrophic disorders in the femoral head, joint decompensation, and irreversible loss of joint function. According to H.J. Robinson et al., intra-articular interventions are very dangerous [11]. D.R. Cooperman et al., caution against the stereotyped performance of acetabuloplasty under conditions of developed aseptic necrosis and indicate the need for the careful study of this problem despite a reasonable outcome of early surgical repair of the articular ratio [3].

Most experts believe that the iatrogenic impairment of local blood circulation plays a leading role in the Perthes disease pathogenesis [3, 9, 23]. The revascularization of the bone can occur through rapid recanalization of damaged vessels or by neoangiogenesis. According to R. Connolly, it is currently not possible to quickly normalize the microcirculation in the femoral head [1]. On the other hand, it can be assumed that known interventions, such as tunneling or osteoperforation, do contribute to the formation of new vessels that can have a stimulating effect on reparative processes in the femoral head [24]. Based on this hypothesis, we included stimulation techniques in surgical measures for treating pediatric patients with hip dysplasia complicated by aseptic necrosis. Nevertheless, a limited number of patients and the absence of a comparison group is a limitation on the conclusion presented about the role of this manipulation in the recovery process in our patient cohort.

Our findings of extra-articular interventions have shown that the presented technology is sufficiently effective. The progression of dystrophic changes were absent in our study population. In most cases, an improvement in the shape of the head and the congruence of the articular surfaces was observed. The results obtained are consistent data previously presented [3, 11, 20]. The observed change in radiometric indices of the proximal femur suggests the possibility of the formation of ischemic deformities at an older age, in the form of hyperplasia of the greater trochanter and shortening of the neck. This is probably due to the fact that the technology did not include the epiphysiodesis of the greater trochanter.

When combining the above reconstructive surgeries with an open reduction of the dislocation, the radiological head shape and articular surface congruence results were worse than with extra-articular interventions. Despite a longer rehabilitation period, full joint mobility recovery was not achieved. A single case of contracture progression was regarded as joint decompensation. Apparently, technology that involves intra-articular manipulations in the case of Perthes disease requires improvement and its use necessitates further study.

Conclusion

Extra-articular reparative surgeries in combination with stimulation interventions and hardware decompression provide conditions for improving the shape and structure of the femoral head, the formation of congruent articular surfaces in pediatric patients with femoral subluxation complicated by aseptic necrosis.

Additional information

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Contribution of the authors

M.P. Teplenky wrote the article.

E.V. Oleynikov was engaged in design of the work.

V.S. Bunov performed data processing and analysis.

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