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LONG-TERM TREATMENT RESULTS OF CONGENITAL HIP DISEASE IN ADOLESCENTS

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Background. An analysis of modern literature reveals that presently, there are no algorithms for determining the correct method of surgical treatment for adolescents with high congenital hip dislocation; few publications are devoted to the treatment of adolescents with this pathology. Children are treated by podiatrists until the age of 18 before transferring to adult specialists. There remain debatable issues of total hip replacement in adolescents because there are time limits for hip preservation. The search for improved treatment methods for adolescents with this pathology by preserving their own bone structures continues to be relevant.

Aim. To evaluate the long-term results of the treatment of adolescents with complete congenital hip dislocation after intertrochanteric osteotomy using the authors' technique.

Materials and methods. From 1990–2006, in the Republican Orthopedic and Traumatological Center of the Republic of Dagestan and the clinic of the Department of Traumatology and Orthopedics of the Dagestan State Medical University, 37 patients with high congenital dislocation of the hip underwent 49 operations using the method developed by the authors. The surgeries were performed by a single orthopedist and were presented as an angulatory lengthening by transtrochantic osteotomy of the femur by fixation with a fingered plate. All patients underwent clinical, radiographical, biomechanical, and statistical evaluation before and after surgery using the Harris and VAS scales. The results of the study were processed using the Student, Pearson, and Kolmogorov coefficients and confidence intervals.

Results. Over a long-term treatment period of up to 10 years, the average Harris score increased from 44.2 (95% CI 38.7–47.9) to 80.5 (95% CI 77.1–85.3). After the 10-year follow-up period (10–15 years after surgery), the scores gradually dropped to 72.4 (95% CI 70.1–78.3). Unsatisfactory treatment results were found in 13.5% of cases and were mainly associated with an unsuccessful choice of support point under the pelvis and the preservation of uncompensated shortening of the limb. The alignment of the created degree of angulation of the hip in terms of adolescent age groups was not established. Differences in treatment results (depending on the inter-operation time for the bilateral dislocation of the hip) were not established. At follow-up periods of 10–15 years after surgery, total hip replacement was performed in 21 joints (56.7%).

Conclusions. The proposed method of surgical treatment of congenital hip dislocation in adolescents improves the static–dynamic capabilities of the hip joint and remains effective over the following 15 years of life. The duration of inpatient treatment is reduced and does not interfere with subsequent total hip arthroplasty.

Keywords: congenital dislocation of the hip; supporting osteotomy of the upper third of the thigh; results.

ОТДАЛЕННЫЕ РЕЗУЛЬТАТЫ ЛЕЧЕНИЯ ВРОЖДЕННОГО ВЫВИХА БЕДРА У ПОДРОСТКОВ

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Обоснование. Анализ современных литературных данных показывает, что и в настоящее время не существует алгоритмов выбора метода хирургического лечения подростков с высоким врожденным вывихом бедра. Публикаций, посвященных лечению подростков с данной патологией, немного. Детские ортопеды наблюдают пациентов до возраста 18 лет, чтобы в дальнейшем передать их другим специалистам. По-прежнему обсуж-

даются вопросы тотального эндопротезирования тазобедренного сустава у подростков, ибо срок их функционирования ограничен. Поиск более совершенных методик лечения подростков с этой патологией путем сохранения собственных костных структур остается актуальным.

Цель — оценка отдаленных результатов лечения подростков с полным врожденным вывихом бедра после ангулирующей межвертельной остеотомии по методике авторов.

Материалы и методы. За период с 1990 по 2006 г. в Республиканском ортопедо-травматологическом центре Республики Дагестан, клинике кафедры травматологии и ортопедии Дагестанского государственного медицинского университета 37 пациентам с высоким врожденным вывихом бедра выполнено 49 операций по методике, разработанной авторами. Операция представляет собой ангулирующую удлиняющую чрезвертельную остеотомию бедра с фиксацией лапчатой накостной пластиной. Все операции выполнены одним хирургом. Всех больных оценивали клинически, рентгенологически, биомеханически, статистически до и после оперативного вмешательства с использованием методики Харриса и визуальной аналоговой шкалы. Результаты исследования обрабатывали с помощью коэффициентов Стьюдента, Пирсона, Колмогорова и доверительного интервала.

Результаты. В отдаленные сроки лечения до 10 лет средний балл по Харрису увеличился с 44,2 (95 % ДИ 38,7–47,9) до 80,5 (95 % ДИ 77,1–85,3). После 10-летнего наблюдения (10–15 лет после операции) количество баллов постепенно уменьшилось до 72,4 (95 % ДИ 70,1–78,3). Неудовлетворительные результаты лечения получены в 13,5 % случаев и в основном связаны с неудачным выбором уровня остеотомии бедра, сохранением некомпенсированного укорочения конечности, болевого синдрома в тазобедренном суставе. Выравнивания созданного угла ангуляции бедра в зависимости от возрастных групп подростков не отмечено. Разница в результатах лечения в зависимости от межоперационных сроков при двустороннем вывихе бедра отсутствовала. В сроки наблюдения 10–15 лет после операции тотальное эндопротезирование тазобедренного сустава выполнено в 21 суставе (56,7 %).

Заключение. Предложенный нами метод хирургического лечения врожденного вывиха бедра у подростков позволяет улучшить статико-динамические возможности тазобедренного сустава, сократить сроки стационарного лечения и не препятствует последующему тотальному эндопротезированию тазобедренного сустава.

Ключевые слова: врожденный вывих бедра; опорная остеотомия верхней трети бедра; результаты.

Surgical treatment of congenital hip dislocation (CHD) in adolescents remains a complex and unresolved problem of contemporary orthopedics.

According to a number of authors [1–3], CHD occurs in 5 per 1000 newborns, 1–2 cases of which are high hip dislocation. In the North Caucasus republics, CHD is 2.8 times more common in adolescents than in the population of the middle zone of the Russian Federation [2]. In the Republic of Dagestan, the traditional tight swaddling is still used, which affects the results of treatment. Thus, a fairly large number of patients reported failures after CHD treatment (Groowe IV), and many patients did not receive any treatment at all until adolescence.

Patients complain of lameness, and pain in both the hip joints and lumbar spine. Intra-articular radical interventions in severe CHD with triple pelvic osteotomy lead to early coxarthrosis and disability. The use of demineralized bone-cartilaginous caps did not give the successful results that were expected. Hip arthroplasty in adolescence is recommended only in the terminal stages of coxarthrosis. Employees of the N.N. Priorov National Medical Research Center for Traumatology and Orthopedics believe that "such mutilating surgeries may have limited indications and are possible only after the closure of the growth plates of the bones and in the most extreme cases when the possibilities of reconstructive surgery are completely exhausted" [3].

According to statistics, in the Russian Federation from 2015–2016, 853 hip arthroplasty surgeries were performed in children and adolescents. For the same time period in England, only 37 surgical interventions were performed in children under 18 years old, a rate 23 times lower than in the Russian Federation [4].

According to the National Orthopedics Center of Japan, the survival rate of endoprostheses in adolescents 10 years after surgery is only 70% [5]. The director of the Kazakh Research Institute of Traumatology and Orthopedics, N.D. Batpenov, after processing statistical data on the population of Kazakhstan, came to the conclusion that hip replacement in people under 30 does not have absolute indications (Batpenov et al., 2015).

At a young age, taking into account physical activity, the survival rate of endoprostheses is significantly worse than in patients belonging to an older age group [6]. In adolescents with high CHD, salvage angulation high hip osteotomies, which are recommended by the Russian Association of Orthopedic Traumatologists, are best indicated [7]. This recommendation is also suggested by the results of the hardware-surgical method of salvage procedures proposed by the school of G.A. Ilizarov in 1984. However, the method of G.A. Ilizarov is not

used in modern clinical practice for two reasons: 1) due to the long terms of inpatient treatment and a significant number of postoperative complications; 2) due to a two-level osteotomy with an S-shaped deformity of the anatomical axis of the hip, which prevents subsequent hip replacement [8].

In fact, an optimal method for the treatment of adolescents with CHD has not yet been developed. At the same time, corrective salvage osteotomy of the femur is still used all over the world in the treatment of diseases of the hip joint in adolescents and adults [9, 10].

This work aimed to evaluate the long-term results of the treatment of adolescents with complete CHD after an angulating intertrochanteric osteotomy according to the authors' technique.

Materials and methods

The results of the treatment of 37 adolescents (49 joints) with high CHD were analyzed. The treatment was performed in the orthopedic department of the N.Ts. Tsakhaev Republic Orthopedic and Traumatological Center and the Dagestan Regional Clinical Hospital from 1990 to 2006. All patients gave informed consent to participate in the study and for surgical intervention (protocol of the meeting of the ethics committee of the Dagestan State Medical University No. 3 dated December 20, 2017). According to this technique, 37 adolescents (49 joints) were operated, 12 of them had bilateral hip dislocation (Groowe IV; 2 boys and 10 girls). There were three times more girls than boys (28 and 9, respectively).

There were 20 patients aged 15–16 years old and 17 patients aged 17–18 years old. In 11 patients, hip dislocation on one side was combined with a subluxation of the contralateral joint. Before admission, eight patients underwent surgery. After treatment according to our method, in the first 2–4 years, the G.A. Ilizarov method was used in seven patients to lengthen the femur. When studying the radiographs of the pelvis in 15 cases, neoarthrosis was located above the acetabulum; in eight cases it was in the middle of the iliac wing. The remaining patients did not have severe neoarthrosis. Anatomical shortening of the limb with unilateral dislocation of the hip ranged from 2 to 6 cm; a symptom of longitudinal slide from 1 to 2 cm was detected in 15 patients (18 joints).

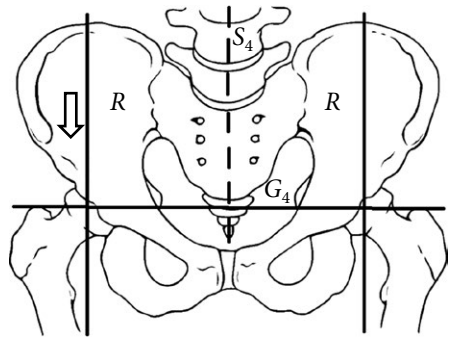


Fig. 1. Schematic representation of the load on the hip joints when a person is standing on both limbs (according to Pouwels)

Our proposed surgical procedures have a biomechanical justification. With CHD, the formation of the hip joint occurs according to the laws of biomechanics. The hip joint is now presented as a modified spherical device. Literary data on the biomechanics of the hip joint are limited. In modern orthopedics, the biomechanics of the hip joint are considered based on the ideas of Pouwels (1950, 1966). In the process of studying the functions of the hip joints during human movement, the level of dynamic forces falling on them was calculated [11, 12].

When a healthy person stands on two legs, the weight of their body bears on the hip joints. The human pelvis rests on the heads of the hips. In a vertical position, the center of gravity of the body, which includes the partial bodyweight of G_4 (head, body, two arms), is directed vertically in the frontal plane (Fig. 1).

Bodyweight of G_4 is concentrated in S_4 and is evenly distributed on both heads of the hips. Thus, each hip joint holds half the body weight of G_4, and the resulting R is directed vertically downward.

A completely different picture is seen when a person is standing on one limb. In this case, the hip joint retains a partial body weight (head + body + two arms + leg weight in the step transfer position). When single-support standing, muscle forces act that prevent the pelvis from tipping over (Fig. 2).

In this case, the leverage system operates by the equation of vectors: $\overrightarrow{hM} = \overrightarrow{d_5 G_5}$. Point S of the vertically acting partial body weight G_5 is shifted to the side of the leg, which is in the transferable period of the step. The lever of the person's load arm is d_5. On the side of the leg on which the person stands, the resulting M (abductor forces) acts with a lever arm of size h. For this reason, the partial weight of the body G_5 on the side of the leg in the position of

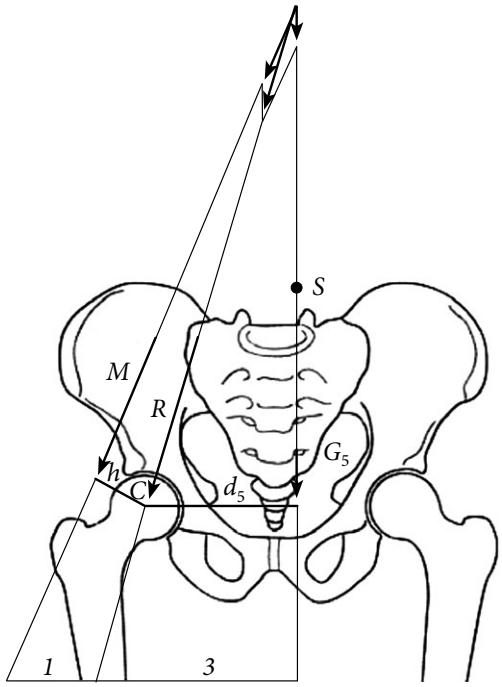


Fig. 2. Schematic representation of the load on the hip joints when a person is standing on the right limb (according to Pouwels)

the transferable period of the step causes a moment of rotation around the femoral head ($\overrightarrow{d_5G_5}$), and it is counteracted by the moment of rotation of the muscular strength of the contralateral side ($\overrightarrow{hM}$). As a result, a system of balancing levers is formed: $\overrightarrow{hM} = \overrightarrow{d_5G_5}$. Pauwels found that the lever arm d_5 is three times longer than the lever arm h of muscle strength M. As a result, the muscle strength of the abductors must be three times greater in order to maintain body balance. The resulting R should be approximately four times greater than the partial bodyweight of G_5.

Pauwels performed similar calculations not only on healthy joints but also with *coxa valga*. The author concluded that with an increase in the collum-diaphyseal angle, the value of the total resulting R increases, which entails an increase in the load on the joint.

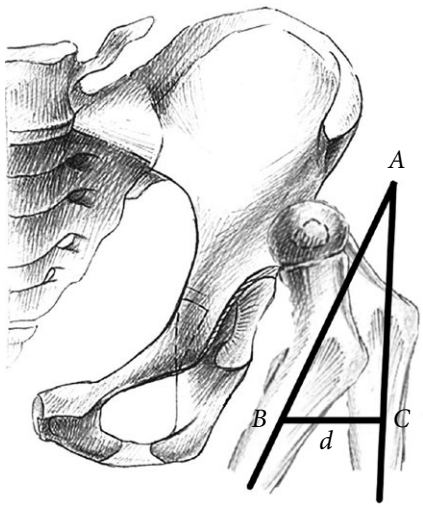


Fig. 3. Schematic representation of the dead phase of step *d*

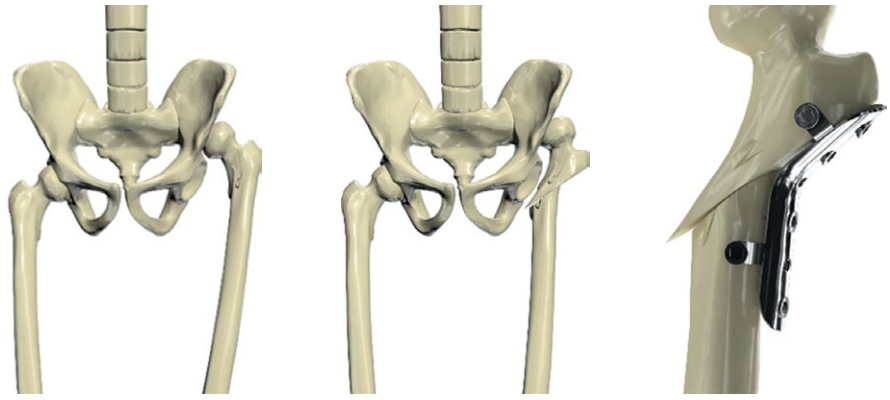
In a healthy person, bodyweight is transferred to the hip joints evenly and at an angle of 45°. With a unilateral CHD, the vertical center of gravity passes closer to a healthy limb. When single-support standing, a person walks with a limp until the hip approaches as close as possible to one of the points of the pelvis. This moment of walking is called the dead phase of the step (Fig. 3). At the same time, pelvic-trochanter muscles keep the pelvis from tipping over in the horizontal plane. Can such a patient be helped in order to stabilize the hip joint and improve gait?

We hypothesized that elimination of the dead phase of a step in a particular adolescent is possible by means of an extra-articular lengthening transversal osteotomy of the hip (patent No. 2614101). Therefore, the primary aspect of surgical intervention for CHD is the correct choice of the support point for the pelvis.

To do this, two X-ray functional images should be taken. The first image of the hip joint meets the generally accepted standards for anteroposterior projection in the supine position of the patient. On the roentgenogram, we assess the degree of development of neoarthrosis and the level of spatial location of the femoral head. The second X-ray of the hip joint is performed in the position of the patient standing with the support of the affected limb. On the radiograph, we evaluate the severity of the symptom of the longitudinal slide of the femoral head and find the point of maximum approximation of the femur to the pelvis. In this case, we form a triangle *ABC*, where *d* is the dead phase of the step (Fig. 3).

We found that the severity of Trendelenburg's symptom depends on the distance d. Therefore, the main purpose of the surgery is to reduce the distance *d*. And if, at the same time, it is possible to eliminate partially or completely the difference in the length of the limbs, lameness will also decrease.

With high CHD and underdeveloped neoarthrosis, the cartilaginous coating of the inner articulating surface of the femoral head, as a result of mechanical friction along the iliac wing, becomes thinner and is eventually worn down to the subchondral bone structures. The femoral head is usually deformed and becomes walnut-shaped, there is a crunch with a load on the limb, and the patient experiences severe pain while walking.



a *b* *c*

Fig. 4. High congenital dislocation of the hip (*a*); a schematic representation of a technique for lengthening support osteotomy of the hip (*b*); a schematic representation of the technique for fixing fragments of the femur (*c*)

Our surgery aimed to valgize the proximal end of the hip and transfer the support load to the cartilaginous surface of the distal portion of the femoral head. Using the oblique transtrochantic pelvic osteotomy it is possible to extend limb length by 3.5 cm while maintaining the biomechanical axis of the limb (patent No. 2614101). The latter circumstance is especially important because hip joint replacement is an indispensable continuation of treatment.

To achieve our aims, we performed an oblique lengthening transtrochantic osteotomy of the hip and the proximal fragment was brought to the pelvis until the soft tissues began to exert elastic resistance. The distal femoral fragment was displaced along the osteotomy line downwards and outwards until the biomechanical axis of the limb was restored. The specified position of the femoral fragments was fixed on the palmiform plate, adapted to the shape of the angular deformity (Fig. 4, *a*–*c*).

Surgical technique. With Langenbeck's access from the great trochanter along the axis of the hip, the skin is incised; and subcutaneous fatty tissue, superficial fascia, and the subtrochanteric region is exposed subperiosteally. Using a special conductor, we bring a Jigley saw around the femur 3 cm below the intended osteotomy point. The hip is transected along its diameter. Then, with a chisel or vibrosaw, we perform osteotomy of the outer cortical part 3–4 cm below the apex of the greater trochanter, obliquely from top to bottom and from the outside inwards until meeting the previous corticotomy line. We obtain two fragments of the hip with an oblique line of fracture in the intertrochanteric and subtrochanteric regions. Behind a small trochanter, we make a notch with a grooved chisel, where we introduce the proximal end of the distal fragment using the guide spoon. With a single-tooth hook, we shift the proximal end of the hip as far down as possible and forward at an angle of up to 20° (Fig. 4, *b*). By approximating the distal part of the hip, we restore the biomechanical axis of the limb. This position of the limb is fixed on the plate of our structure. We drain the wound and suture it tightly.

Thus, an angle of 140–150° to the longitudinal axis of the hip is formed, which is open outwardly, and the proximal end is approached to the pelvis as much as possible and rotated with respect to the sagittal plane within a range of 20°. The total length of the hip is increased by 3–4 cm. The average hospital stay is 15–20 days. Restorative treatment and exercise therapy begin seven days after the surgery and continue at home.

Results

Clinical results were evaluated according to the Harris scheme in the follow-up period from 8 to 20 years (Table 1): namely up to 10 years in 22 patients, up to 15 years in 13 and up to 20 years in 2 patients. It should be noted that postoperative data on the Harris scale differed markedly from preoperative data with high statistical reliability ($p < 0.0001$) and were characterized by certain aspects.

The average Harris score before surgery was 44.2 (95% CI 38.7–47.9). After the surgery, during the first 10 years, the average score reached 80, and by the year 15 of follow-up, it decreased to 72.4 with a high degree of statistical reliability (see Table 1).

Shortening of the limb before surgery was 38 mm (95% CI 22–56), minimum 20 mm and maximum 60 mm. During the surgery, the limb length changed on average by 34 mm (95% CI 28–39).

Table 1

Clinical evaluation of treatment outcomes for high congenital hip dislocation in adolescents on the Harris scale (95% CI)

Average score before surgery, n = 37	Average overall score 8–10 years after surgery, n = 22	Average overall score 15 years after surgery, n = 15	Number of unsatisfactory results	Number of endoprosthetics
43.3 38.7–47.9	77.6 (77.1–85.3)	74.2 (70.1–78.3)	5 13.5%	21 (56.7%)

The main lengthening of the limb occurred due to valgization of the upper end of the hip (up to 20 mm), displacement of the distal fragment and abduction by up to 10–13 mm, removal of the symptom of longitudinal slide of the femoral head by an average of 8–9 mm. However, the difference in the length of the limbs was completely eliminated only in seven patients, in which femoral elongation was performed using the Ilizarov apparatus.

In general, we registered satisfactory and good outcomes, and no dependence of the result on age was revealed (Table 2).

Satisfactory and good treatment results were obtained in the majority of patients (75.7%), while poor results were noted in five patients (13.5%), and mainly in patients with unilateral hip dislocation. No dependence of treatment results on age was reliably detected, although there was a minimal difference in numbers in young patients.

Most cases with an unsatisfactory outcome are associated with an incorrectly selected support point under the pelvis at the beginning of the study and the condition of the joint before surgery.

The treatment results on the visual analog pain scale (VAS) were as follows. Before surgery, the VAS score was 3–4 points (from 2 to 5 points), but in the first 10 years of follow-up, the average score was 1–1.5 (95% CI 1.3–1.8). The pain syndrome gradually progressed, and by the year 15 of follow-up, patients rated it at 4–5 points. Accordingly, excellent and good treatment outcomes after a 15-year follow-up were absent in patients of all age groups. To date, total hip arthroplasty has been performed in 21 patients in various clinics of the Russian Federation (56.7%).

Table 2

Characterization of the functional results of the surgery after 20 years

Functional result	Patient's age		Total results, %
	15–16 years	17–18 years	
Excellent	2	2	10.8
Good	4	2	16.2
Satisfactory	12	10	59.5
Poor	2	3	13.5

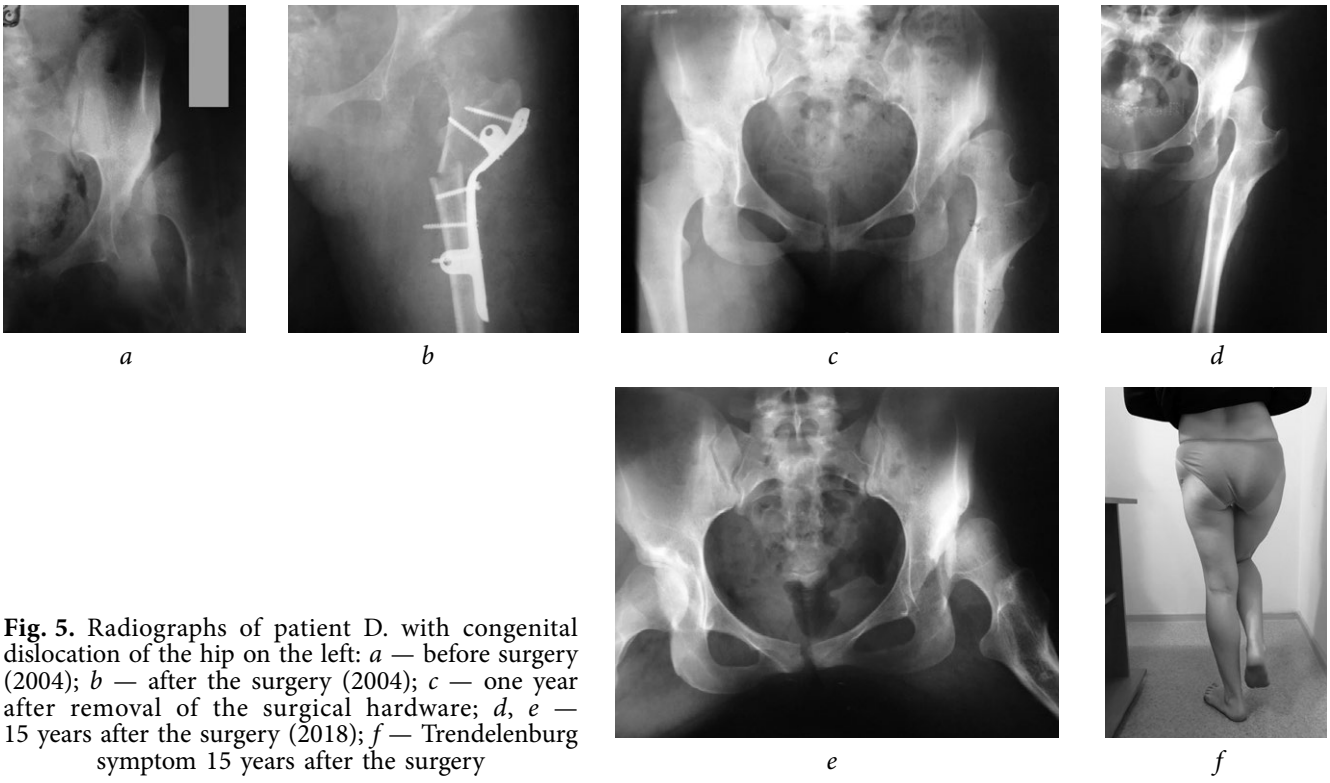
There was no statistically significant effect of interoperative periods in bilateral hip dislocation. There were no complications in the postoperative period in the form of suppuration or failure of surgical hardware. Isolated cases of suppuration around the spokes of the Ilizarov apparatus were noted; the complication was completely eliminated after injection of antibiotics to the soft tissues.

As an example, we provide a brief extract from the medical record No. 3-208.

Patient D.L., 15 years old, was admitted to the orthopedics department of the Republican Orthopedic and Traumatological Center of the Republic of Dagestan in 2004 with a diagnosis of peri-acetabular congenital dislocation of the left hip. In accordance with the anamnesis, the diagnosis of congenital dislocation of the hip was established at the age of 5 months, the patient was treated at the primary healthcare facility in the children's department of the DRCH. An attempt was made to close the dislocation of the left hip dislocation with fixation in a plaster cast in a position close to Lorentz I and II, with a total fixation period of 5 months. Control radiographs of the hip joint revealed a relapse of the left hip dislocation. No further conservative treatment was performed.

At the age of 15 years, the patient was admitted with complaints of pain in the hip joint on the left, lameness, shortening of the limb by 4 cm. The radiograph revealed a dislocation of the left hip with moderate neoarthrosis in the peri-acetabular region, subchondral sclerosis (Fig. 5, *a*). After the examination, taking into account the X-ray image, the patient's age and clinical data, in 2004 a surgical intervention was performed according to the technique we proposed (Fig. 5, *b*). The postoperative period was uneventful. The wound healed by primary intention. After a week, rehabilitation treatment was started, the patient was trained in rehabilitation treatment and was discharged home after 14 days with the use of a "derotational boot" for 2 months.

A year later, the hardware was removed (Fig. 5, *c*) and rehabilitation treatment continued. A follow-up



a *b* *c* *d* *e* *f*

Fig. 5. Radiographs of patient D. with congenital dislocation of the hip on the left: *a* — before surgery (2004); *b* — after the surgery (2004); *c* — one year after removal of the surgical hardware; *d*, *e* — 15 years after the surgery (2018); *f* — Trendelenburg symptom 15 years after the surgery

examination was performed 15 years after surgery (2018); there were no complaints — the patient walked with a full load on the limb, without additional support, with a slight limp on the left lower limb. Functional shortening of the left lower limb by 1.5 cm is noted. The radiograph of the left lower limb reveals a restored biomechanical axis of the limb. The proximal end of the hip is valgized, the collum-diaphyseal angle is 145°, and the support points for the pelvis have been formed in the region of the lower edge of the acetabulum and a small trochanter (Fig. 5, *d*, *e*). The patient is married, has two children, is employed, and she is satisfied with the result of the surgery. The Trendelenburg symptom is not prominent (Fig. 5, *f*). Periodically, in the summer, she undergoes independent rehabilitation treatment in the territory of the North Caucasus. With a prolonged load on the limb, a minor pain syndrome is noted, which decreases with intake of non-steroidal anti-inflammatory drugs. The patient is not yet ready for hip joint replacement.

Discussion

According to several authors, CHD ranks first among congenital pathologies of the musculoskeletal system [13, 14]. Patients note that pain in the hip joint with CHD becomes apparent at the age of 13–14 years. In treatment of marginal dislocation of the hip, triple pelvic osteotomy with transposition of the acetabulum and complete overlap of the femoral head is an effective treatment method [15]. When treating the same pathology (Grow IV), salvage surgery (corrective osteotomy of the hip, acetabuloplastic shelves) is performed in adolescents and children of older age, or conservative treatment is performed until the age of 18 to transfer patients to orthopedists treating adult patients. And the latter prefer total hip arthroplasty, although it is possible to perform organ-sparing surgical interventions in adolescents [15].

We do not deny the revolutionary results of total hip arthroplasty in adolescents, especially since there are works that demonstrate the experience of such surgeries in children (268 patients), although long-term results are not presented [16]. It should be borne in mind that the age of patients affects significantly the terms of arthroplasty. A high degree of vitality and the intensity of physical exertion in adolescent patients after total hip arthroplasty is proportional to the static-dynamic stress and is reflected in the "survival rate" of the endoprosthesis [17–21]. Ultimately, the statement of Jona Charnley is justified: "To date, there is no endoprosthesis that can be installed to a young patient for his entire lifetime."

We treated 37 adolescent patients (49 joints) in the period from 1990 to 2006, who underwent surgery with preservation of their own bone structures. All patients complained of severe pain in the hip joint while walking and of hyperlordosis.

The starting point for the initiation of these surgical interventions was the method of angulating double osteotomy of the hip according to the Ilizarov–Schanz method. Such supporting osteotomies were aimed at the formation of support points under the pelvis in the ischium. We noted a number of complications during treatment and long-term inpatient follow-up, taking into account the experience of treatment according to Ilizarov. In addition, the hip was subjected to S-shaped deformity, which significantly hindered subsequent hip replacement.

In order to eliminate these disadvantages, we used the biomechanical principle for supporting hip osteotomies with high CHD (1985). We found that the CHD patient limps until the hip is as close to the pelvis as possible. The greater this distance, the so-called dead phase of the step, the more prominently the patient limps. We have developed various options for reducing the length of this phase of the step in combination with the simultaneous elimination of shortening of the lower limb. The main aspect of the surgery is oblique intertrochanteric osteotomy of the hip with the proximal fragment being brought to the pelvis until the sensation of elastic resistance of soft tissues arises.

Surgical interventions have become much more feasible compared to the method of using the external fixation apparatus. The maximum stay of patients in the hospital was three weeks; seven days after the surgery, an early period of rehabilitation began. The total length of the limb increased to 3.5 cm or more. However, the complete elimination of the difference in the length of the limbs was achieved only by lengthening the hip according to Ilizarov's method.

Good and satisfactory treatment results were obtained in 75.7% of cases; poor results were registered in 13.5% of cases. After 10 years of follow-up, the results of treatment according to Harris deteriorated, pain according to VAS was initially estimated at 8–9 points, and at the end of the 10-year period, at 4–5 points. Endoprosthesis replacement surgery with total hip arthroplasty according to the Paavilyaynen technique was performed in 21 patients (56.7%).

The main disadvantages of the Schanz surgery included 1) the presence of rods passing through soft tissues and plaster, which often resulted in wound infection; 2) osteotomy and the creation of angular deformity of the hip led to a significant shortening of the limb; 3) creation of an abduction angle closer to the middle third of the hip contributed to a sharp limitation of limb adduction and the appearance of an atypical static-dynamic gait; 4) upon medialization of the distal femur fragment, genu valgum developed and the load on the external condyle increased, followed by occurrence of gonarthrosis; 5) deformity of the axis of the hip created obstacles to hip replacement; 6) the biomechanical axis of the hip was disrupted, which led to functional insufficiency of the gluteal muscles and the development of severe contractures in the hip joint.

The noted disadvantages of the Schanz surgery were partially eliminated in the apparatus-surgical method of treating high CHD developed by Ilizarov. Schanz's idea of creating a hip rest by means of an angulating osteotomy was retained, and shortening of the hip and restoration of the biomechanical axis of the limb were eliminated by lengthening the hip in the author's external fixation apparatus.

Methods for treating CHD in adolescents and adults, suggested by the G.A. Ilizarov school, had practically the same disadvantages as the methods of Schanz. The main advantage was hip lengthening and stabilization of gait. However, the insertion of wires through the greater trochanter and gluteal muscles led to the development of infection around the spokes and severe pain. The long-term inpatient treatment (up to 5–6 months) negatively affected the health care economy. Ultimately, after 10–15 years, severe contractures of the hip joints occurred in the patients. The S-shaped hip axis deformity prevented the inevitable hip arthroplasty.

In contrast to these methods, in order to eliminate the above disadvantages in patients with high CHD (Groowe IV) based on the biomechanical parameters of walking, we proposed a new principle for the creation of supporting hip osteotomies. First, we abandoned low hip osteotomy, since it is impossible to calculate accurately the level of hip osteotomy. We performed oblique periosteal osteotomy of the hip, starting 3 cm below the apex of the greater trochanter and ending behind the small trochanter. Only the proximal femur fragment was moved anteriorly and inwards to the maximum until elastic resistance of the soft tissues of the pelvis occurred. By osteotomy and displacement of the femoral fragments along the oblique line, we lengthened simultaneously the anatomical length of the limb by the length up to 3.0–3.5 cm and restored the biomechanical axis of the limb. Instead of external fixation apparatuses or Schanz screws, an extramedullary angularly

curved palmiform metal plate was used to fix fragments of the hip, which enabled a reduction in the patient's hospital stay to two weeks.

Lengthening oblique valgizing intertrochanteric osteotomy of the hip eliminated lumbar spine hyperlordosis and helped prevent early osteochondrosis and spondylarthrosis, reduce pain, stabilize gait, and restore preoperative range of motion in the joints of the lower extremities.

Compared to the Schanz surgery, for 10–15 years after our intervention, an adolescent could lead a free life, study at school and then at university, get a profession, get a job, get married, and have children.

Valgization of the proximal end of the hip and bringing it to the pelvis reduced or removed pain in the hip joint, and helped stabilize the gait. Functioning conditions of abductors and tension of the gluteal muscles improved. It should be emphasized that the main load fell on the lower pole of the femoral head, where the cartilage cover was preserved.

Conclusion

Our methodology for treating CHD in adolescents improves biomechanical conditions for the functioning of the abducting muscles of the hip by creating and using new compensatory capabilities of the hip joint. We managed to eliminate simultaneously or reduce the manifestations of the Trendelenburg symptom, stabilize the position of the pelvis, maintain the function of the knee, hip joints in the same volume and increase the anatomical length of the limb by 3.5 cm on average.

Studies reveal the effectiveness of the proposed technique of angulating extending osteotomy of the hip with CHD. The method can be used in young patients with high CHD, especially in cases where the joint replacement is contraindicated.

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Ethical consideration. The study was performed in accordance with the ethical standards of the Helsinki Declaration of the World Medical Association and approved by the local ethics committee of the Dagestan State Medical University (protocol No. 3 dated December 20, 2017).

Informed consent to conduct the study without identification was received from legal representatives of all patients.

Contribution of authors

A.A. Abakarov conducted the search for scientific articles in electronic databases of medical information (PubMed and eLibrary), translated the articles, performed data analysis, wrote the text, studied long-term treatment results, and performed statistical data processing.

A.A. Abakarov (senior) performed stage and final editing of the text of the article and developed the study design.

All authors made a significant contribution to the research and preparation of the article, read and approved the final version before its publication.

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