doi: 10.21823/2311-2905-2019-25-3-9-24

Is the Any Clinical Importance for Separation Congenitally Dislocated Hip in Adults into Types C1 and C2 by Hartofilakidis?

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Abstract

The main questions of the study: 1) is there any difference in anatomical features between subtypes C1 and C2 of high hip dislocation by Hartofolakidis classification; 2) are the conditions for performing the THA different and what are the surgical decisions; 3) what are the THA results in different groups? ***Materials and Methods.*** In a single center study the authors retrospectively evaluated the outcomes of 561 THAs performed in 349 patients with a high hip dislocation including 32 men (9.2%) and 317 women (90.8%) with the follow up from 12 to 188 months (average 69,4 months). In 326 cases (58.1%) the dislocation was assessed as type C1, and in 235 cases (41.9%) — as type C2. The average age of the patients at the time of surgery was 47.6 (19 to 74) years, for men — 39.1 years and 48.1 years for women. ***Results.*** Paavilainen shortening osteotomy was performed in 100% of patients with type C2 and only in 50.6% of patients with type C1, $p<0.001$. The cup was implanted into the true acetabulum cavity in 99.1% of cases with type C2, and for type C1 only in 69.0% of cases, $p<0.001$. Lateral under-coverage of the cup in patients with type C2 required supplementing by femoral head autograft only in three cases, and for type C1 — in 18 patients, $p = 0.009$. In the group of C2, the mean length of the osteotomized fragment of the proximal femur was 78.6 mm compared to 62.5 mm in patients with type C1. This provided a better contact area between the greater trochanter and the femur and in 92.8% of cases fixation was done by cerclage wires and two screws. In the group of patients with type C1, this option was feasible only in 60.0% of cases. Odds ratio (OR) for fixation of the greater trochanter by a special plate for primary indications in patients with type C1 were 10 367, $p = 0.008$. Harris Hip score improved averaged from 39.5 points to 83.6, without statistically significant differences between groups of C1 and C2. Early complications included 9 dislocations (1.6%), 8 cases of femoral nerve neuropathy (1.4%) and 3 early infections (0.5%). No cases of sciatic nerve paresis were observed. Non-union of the greater trochanter was observed with almost equal frequency in patients with C1 and C2 types, and revision fixation was needed in 27 patients (6.8%). Revision arthroplasty was performed in 22 cases (3.9%) due to 4 infections, 2 aseptic loosening of the stem, 11 aseptic loosening of the acetabular component and 5 recurrent dislocations. ***Conclusion.*** The group of patients with high hip dislocation is very heterogenic in terms of severity of anatomical changes and demands different surgical tactics. Hartofolakidis classification helps the surgeon to select the best type of the surgical procedure, minimize the mistakes and predict treatment outcomes.

Keywords: hip dysplasia, high hip dislocation, classification, hip arthroplasty.

Cite as: Tikhilov R.M., Shubnyakov I.I., Denisov A.O., Pliev D.G., Shubnyakov M.I., Vahramyan A.G., Avdeev A.I. [Is the Any Clinical Importance for Separation Congenitally Dislocated Hip in Adults into Types C1 and C2 by Hartofilakidis?]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2019;25(3):9-24. (In Russian). doi: 10.21823/2311-2905-2019-25-3-9-24.

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Received: 30.07.2019. Accepted for publication: 31.08.2019.

Introduction

Today arthroplasty of the hip joint (HJ) is considered the most effective surgical treatment of symptomatic arthritis while the most common reason for secondary arthritis of the HJ is progressive dysplasia [1, 2, 3, 4]. At the same time dysplastic osteoarthritis according to many authors poses a greater issue in joint replacement in contrast to idiopathic osteoarthritis especially in cases of maximum grade of dysplasia with high hip dislocation [5, 6, 7, 8]. Congenital hip dislocation holds a relatively small share in the overall structure of HJ arthroplasties — less than 1% of all replacements according to the Norway register*.

As a rule, severe anatomical alterations of the acetabulum that limit secure cup fixation and complicate the choice of friction couple due to small size of acetabular component, significant shortening of the leg and related need for specific surgical techniques and difficulties in application of a standard femoral component [5, 6, 9, 10, 11] are considered the key arthroplasty challenges in patients with high hip dislocation. In such cases cup positioning into the true acetabulum results in the need for substantial lengthening of the operated limb, in certain cases up to 8-9 cm, which is impossible to achieve avoiding major damage to surrounding muscles and traction lesion of sciatic and femoral nerves [12]. In cases of severe cranial displacement of the femoral head to prevent such complications the joint replacement is performed in combination with shortening femur osteotomy, which results in lengthening only of 2.0-3.5 cm and preservation of all key functional structures. All potential advantages and disadvantages of various types of subtrochanteric shortening osteotomy and of proximal shortening osteotomy with distal transfer of the greater trochanter are described in a great deal of scientific publications [5, 16, 17, 18]. The following questions arise: how comparable are the clinical situations when shortening osteotomy is needed and when it's possible to avoid it by cranial transfer of the acetabular component and a deeper positioning of the stem, do we really refer to the same type of dysplasia?

Many classifications are used for assessment of HJ dysplasia grade in adults [19, 20, 21, 22] and the most commonly used is the classification of Crowe et al presented back in 1979 [19]. Simple division into four types depending on the degree of cranial displacement of the head in relation to the true acetabular cavity calculated as a percentage of pelvis height or head diameter provides high reliability and reproducibility, however it doesn't describe all potential complexities of the arthroplasty. Another commonly used classification of Hartofilakidis et al takes into account both head displacement and changes in the acetabular cavity and stipulates three grades — dysplasia (type A), low dislocation (type B) and high dislocation (type C) [21]. Later the authors divided B and C types for subtypes of B1-B2 and C1-C2 [23]. Moreover in their further research authors demonstrated the difference in clinical outcomes of the patients with pathology of C1 and C2 types [24].

Annually over 50 patients with high hip dislocation are operated in our hospital. Basing on the substantial experience in surgical treatment of such pathology we made an attempt to understand the anatomical variances between C1 and C2 types of high hip dislocation (1); are the conditions for performing the THA in such patient different (2) and what are the outcomes of joint replacement in the both groups (3).

* Norwegian National Advisory Unit on Arthroplasty and Hip Fractures, Report, June 2018, http://nrlweb.ihelse.net/eng/

Materials and methods

Study design

The present work is a single center retrospective study. From 2001 to 2016 683 total hip arthroplasties (THA) in patients with high hip dislocation were performed in one surgical unit. Severe pain or the need to improve movements and daily activity were indications for arthroplasty. The authors retrospectively evaluated outcomes of 561 surgeries in 349 patients — 32 (9,2%) men and 317 (90,8%) women. Treatment outcomes were followed in 82,1% of cases from 12 to 188 months (average of 69,4 months). Other patients were lost to follow up. The authors analyzed medical records, technical specifics of surgical procedure and functional assessment of the joints in mid and long term period depending on roentgenological features of the patients.

Patients

Mean age of patients at the moment of surgery was 47.6 years (95% CI from 46.7 to 48.7). There were certain age variances in men and women — 39.1 years (from 20 to 66) and 48.1 (from 19 to 74), respectively, however, no age variances were observed in the patients with different types of high dislocation. In 473 (84.3%) cases arthroplasty was the primary joint procedure, in remaining 88 cases (15.7%) of 82 patients there was a history of earlier various surgeries (femur osteotomies, open reduction of dislocation, pelvic osteotomies and shelf arthroplasty).

Medical records contained data on age and gender of patients, time of surgery and blood loss. Clinical evaluation included functional status by Harris score and difference in length of the legs. Imaging analysis was done on the basis of plain pelvic x-rays prior to and after the surgery. Position of rotation center for the head of the femoral component was measured vertically from the line connecting tear drop signs and horizontally from Kohler line. X-rays were also used to assess the absolute value of distal displacement of the greater trochanter (shift in positioning of the tip of the greater trochanter with respect to the line connecting tear drop signs), contact area of the trochanter with lateral femur surface, lengthening of the leg and time of bone consolidation for osteotomized fragment of the greater trochanter after osteotomy. Roentgenological difference in leg length prior to surgery was evaluated clinically and by comparing positions of the tip of the greater trochanter on the operated and contralateral joints. While shift in position of the tip of the greater trochanter was not equivalent to the leg lengthening, the evaluation of lengthening was calculated as a difference by comparison of preoperative and postoperative X-rays and adjusted considering the value of X-ray magnification, as a difference between the shift distance for tip of the greater trochanter against the line connecting tear drop signs, and contact distance between the greater trochanter and the femur.

Surgical technique

Standard THA through a straight lateral approach was performed in 144 (25.7%) of cases. Approach with a slide osteotomy of the greater trochanter was used in 17 (3.0%) of cases. Shortening Paavilainen osteotomy [25] was used in remaining 400 cases. However, in contrast to the original technique the authors preserved the attachment of *m. vastus lateralis* in the majority of procedures, partially detaching the muscle from the greater trochanter only in case of a very short trochanter fragment [26].

After incision of stretched hypertrophic capsule the authors evaluated position of the true acetabulum usually filled by adipose tissue and sometimes present in the form of a narrow gap. Anterior wall was visualized (usually very thin and underdeveloped) using retractors, then postero-superior bone stock was examined in direction of which formation of acetabular component bed was prepared, usually starting from the smallest cutter size of 36mm. In case of sclerotic bone in the area of true acetabulum due to constant contact with the lesser trochanter, entering the true acetabulum was made using chisel and continued a by cutter. Starting from 30-40 size of cutter cavity formation was done manually with cutter retrace to impact weak bone. Antero-posterior (sagittal) size of the cavity determined the cup size, in cases of a very thin postero-superior wall the cup was inserted a bit caudally.

Guided longitudinal osteotomy of 6 to 10 cm was performed in cases of too narrow bone canal using preventive cerclage wiring in distal and proximal area prior to rasping or using conical drills [26].

Standard fixation after transposition of the greater trochanter included cerclage wires and two cortical screws (3.5 mm). In case of a long fragment of proximal femur the authors used more screws and in case of a very short fragment less screws or a special trochanteric plate was used. Over-elongation of *m. vastus lateralis* due to bone shortening was compensated by muscle suturing with duplication in the area of the base of the greater trochanter.

Postoperative treatment

In the majority of cases antibiotics prophylaxis continued for 24 hours after surgery but in patients with high risk of infectious complications especially prior surgeries on the operated joint longer antibiotics therapy was applied. Low molecular weight heparins changing to warfarin or oral anticoagulants were used for prophylaxis of thrombosis. Only limitation of "unsafe" movements was used for prevention of dislocations and no external devices (braces, bandages, etc). On day 1 after the surgery patients were supposed to do static exercises for muscle contractions and ankle movements. On days 2-3 patients were allowed to walk with two crutches and limiting weight load to only one limb. 6 weeks postoperatively patients were allowed to walk with crutches with partial load which was increased gradually. Patients stopped to use crutches when feeling safe without additional support (usually within 3 months postoperatively).

Statistical analysis

Obtained statistical data was processed by IBM SPSS Statistics for MacOS (version 24) software. Confidence interval of 95% was calculated for mean value and minimum and maximum values in the data series were reported. Numerical parameters in groups and subgroups were compared using the Mann–Whitney U-test and the ANOVA. The frequency response of the numerical criteria was compared using the nonparametric criterion χ^2. Differences were considered statistically significant at $p<0.05$.

Results

Variances of anatomical alterations

Bilateral dislocation was observed 1.8 times more often than unilateral — in 224 (64.2%) and 125 (35,8%), respectively. C1 bilateral dislocation was reported in 74 of 224 patients (33.0%), C2 — in 64 (28,6%) patients, and combined C1 and C2 was the most widespread — in 86 (38,4%) of cases. Unilateral high dislocation was most often classified as C1 type — 93 cases of out of 125 (74.4%). C1 group of patients included 1.6 times higher number of patients with prior surgeries — 61 out of 326 (18.7%) as compared to 27 out of 235 (11.5%) in C2 group.

Majority of patients with unilateral high dislocation (109 (31.2%) patients) had dysplastic changes of varying grades in the contralateral joint (types A, B1 and B2), three patients (0.9%) underwent arthrodesis earlier and five patients (1.4%) had prostheses implanted into the contralateral hip joint, however the authors failed to find out the reason for earlier joint replacement. Only in 8 cases (2.3%) contralateral joints were free of any evident pathological process.

Pelvis under-development on the side with the more severe dislocation was often observed in patients with unilateral high dislocation and with combined dislocation subtypes, which was never observed in patients with equal hips displacement (Fig. 1).

In unilateral pathological process of C2 subtype no difference in pelvis dimensions were reported only in 15.6% of cases (5 out of 32), in unilateral C1 subtype — in 30.1% of cases (28 out of 93) and in patients with combined C1 and C2 — in 27.9% of cases (24 out of 86).

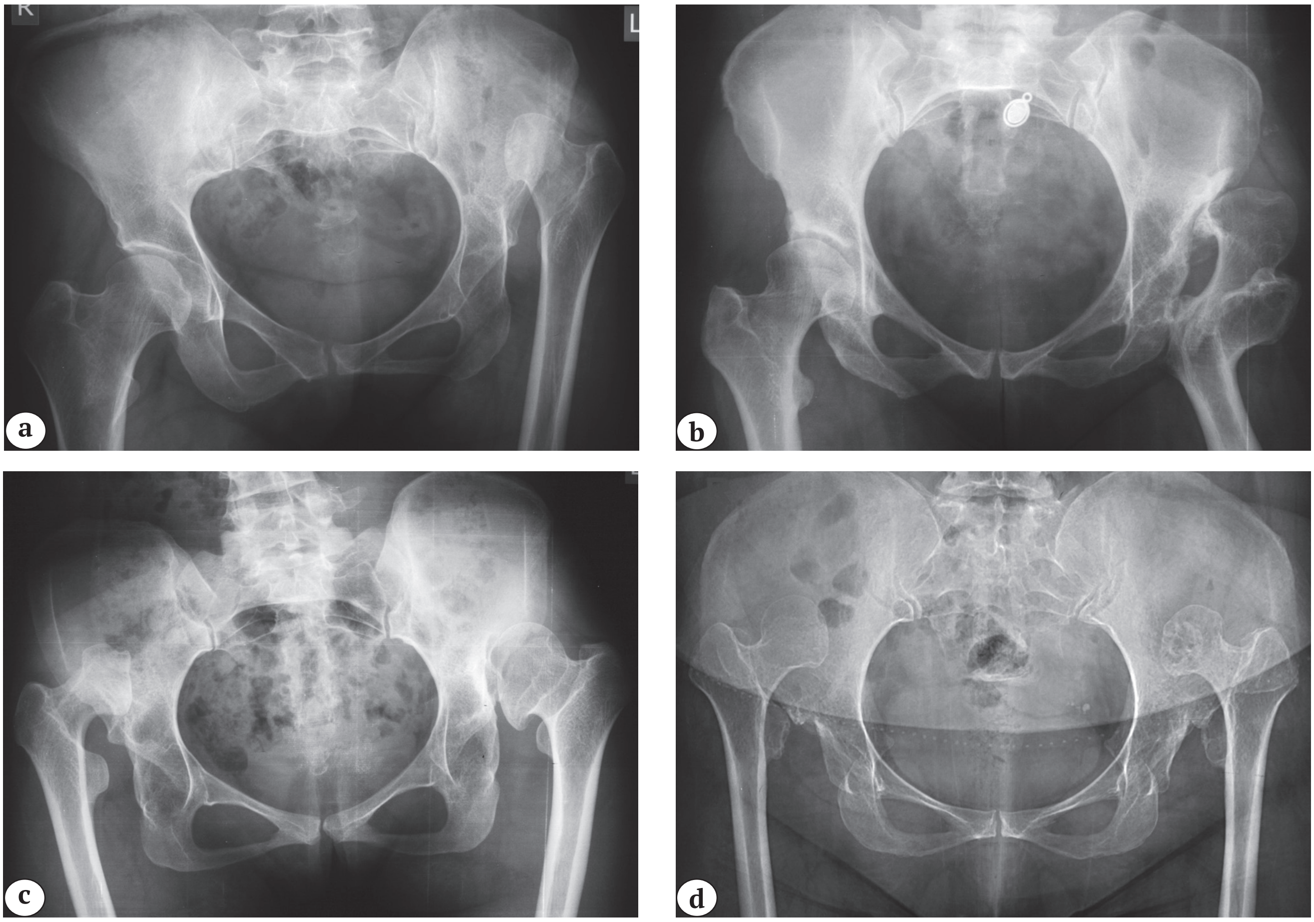
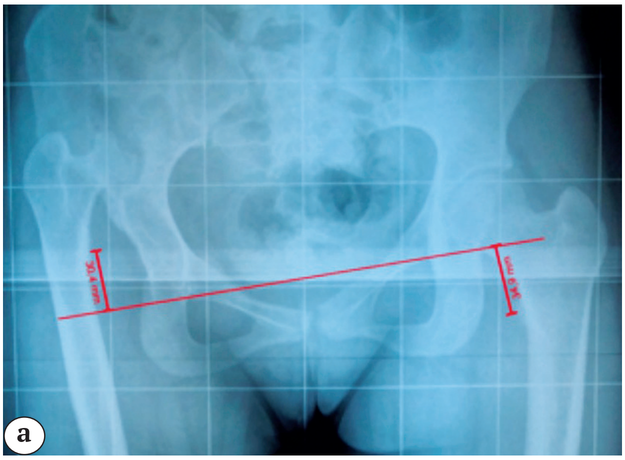


Fig. 1. Various combinations of dislocations and their impact on pelvis dimensions:
a — unilateral C2 dislocation, significantly smaller size of pelvis part on the side of dislocation;
b — unilateral C1 dislocation, significantly smaller size of pelvis part on the side of dislocation;
c — combination of two dislocation types (C2 on the right and C1 on the left), lower height of pelvic part on side of C2;
d — bilateral C2 dislocation — same dimensions of pelvis on both sides;
e — bilateral C1 dislocation — same dimensions of pelvis on both sides

Naturally, the difference in length of legs measured based on the lesser trochanter positioning in respect of the line connecting tear drop signs was significantly higher in cases of unilateral dislocation. However, the real difference assessed by tele-roentgenograms of the lower limbs in many cases was less than value measured on plain pelvic X-rays* (Fig. 2).

With that the mean shortening value was 1.3 times less in patients with C1 subtypes in contrast to C2 (p<0.001) (Table 1).



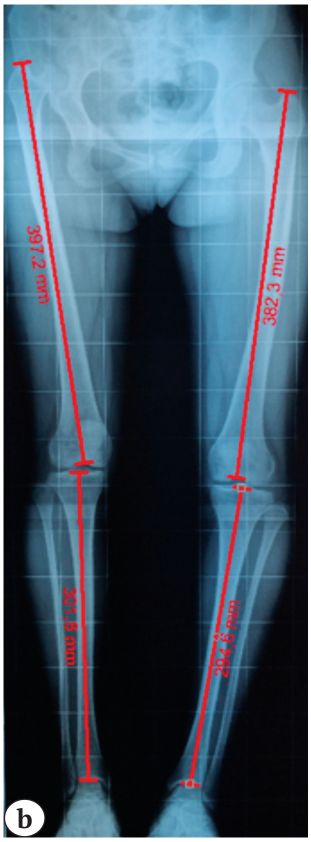


Fig. 2. X-rays of female patient, 48 y.o., unilateral high hip dislocation of C2 by Hartofilakidis:
a — shortening of the operated limb amounts to 65.3 mm by planning based on the overall pelvis X-ray;
b — right tibia shortening of 6mm and right femur shortening of 14.1 mm identified based on teleroentgenograms in comparison to contralateral limb. Correspondingly, the measurement error basing on pelvis X-ray amounts to 20.1 mm, and the value of length correction is 45.2 mm

Table 1

Anatomical features of patients with C1 and C2 dislocation subtypes by Hartofilakidis classification

Criteria	Group		*p* value	Total
	C1	C2		
All hip joints, n (%)	326 (58.1%)	235 (41.9%)	–	561 (100)
Age, average (min-max), years	48.7 (23–74)	46.8 (19–74)	0.098	47.6 (19–74)
Displacement value of femoral head, average (min-max), mm	47.6 (29–55)	63.4 (41–78)	<0.001	52.8 (29–78)
Femoral offset from the femoral axis to the center of femoral head, average (min-max), mm	50.1 (37–63)	44.3 (34–52)	<0.001	47.2 (34–63)
Supra-acetabular osteophytes, n (%)	203 (62.3%)	0	<0.001	203 (36.2)

* Tikhilov R.M., Shubnyakov I.I., Denisov A.O., Boyarov A.A., Cherkasov M.A. [Nuances of preoperative planning of total hip arthroplasty in patients with hip dysplasia]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2015;(4):5-14. (In Russian). doi: 10.21823/2311-2905-2015-0-4-

In cases of contact between femoral head and pelvic bones (type C1) a false cavity was formed appearing as sclerotic plate or a solid supra-acetabular osteophyte which could serve as an additional support to acetabular component (Fig. 3). Besides the majority of patients with C1 subtype demonstrated a more developed proximal femur with average offset of 50.1 (37-63) mm in contrast to 44.3 (34-52) mm of C2 subtype (p<0.001) (Fig. 4).

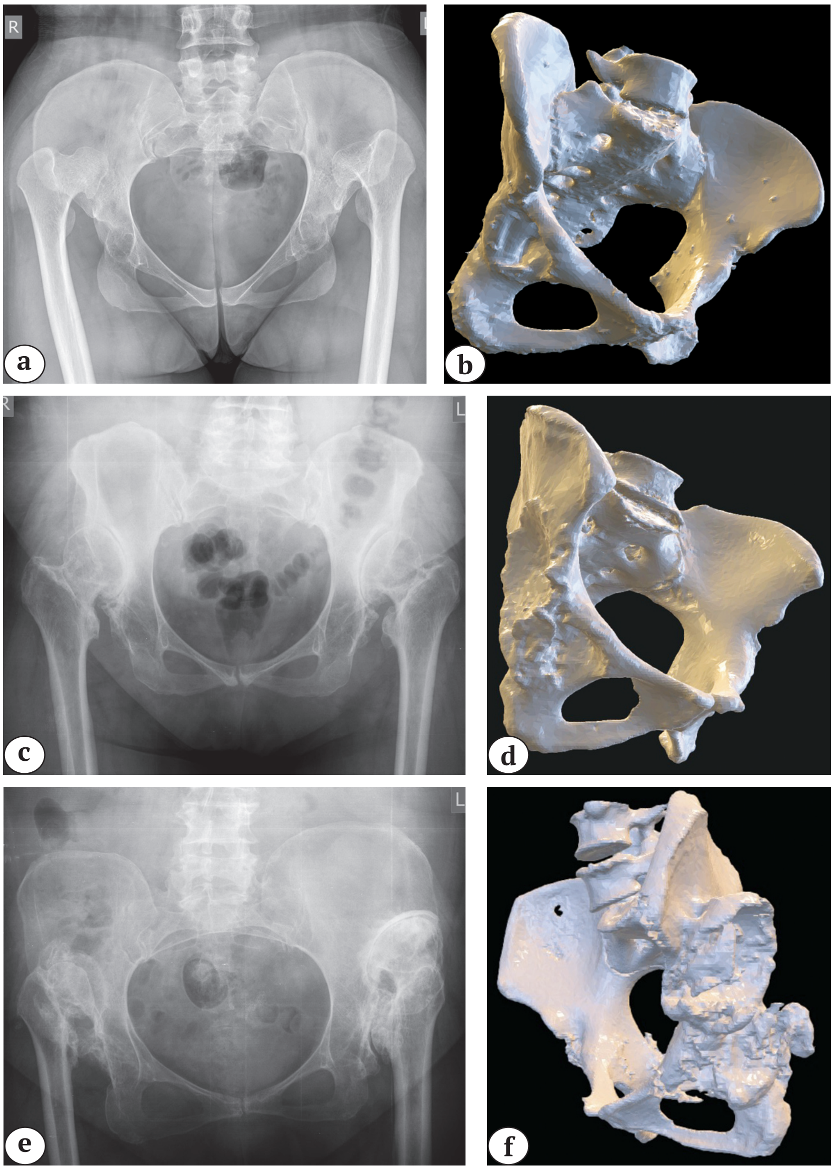


Fig. 3. Pelvis X-rays and 3D visualization of the acetabulum in patients with different dislocation patterns:
a, b — no false acetabulum in C2 type;
c, d — false acetabulum in C1 type represented by a sclerotic zone in the iliac bone;
e, f — full-fledged false cavity with massive supraacetabular osteophyte which allows to perform cranial displacement of the acetabular component

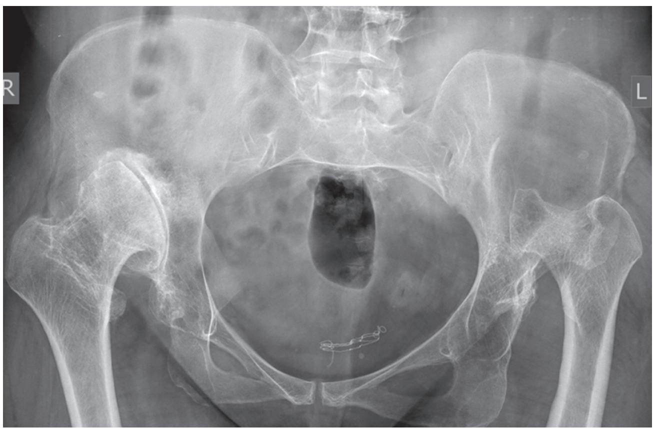


Fig. 4. Pelvis X-ray of female patient, 48 y.o., bilateral high dislocation: C2 type on the left, visualization of the typical proximal femur shape — narrow round canal with ill-defined femoral neck and head; C1 type on the right — clear taper type femoral canal, normal dimensions of femoral neck and head

Specifics of THA in various types of high dislocation

A series of features was observed during hip arthroplasty — shortening osteotomy was performed in 100% of patients with C2 subtype and only in 50.6% of patients (165 joints) with C1 subtype (*p*<0.001). In 17 cases (5.2%) of C1 subtype slide osteotomy was used (15 cases) or subtrochanteric osteotomy (2 cases), remaining 144 (44.2%) surgeries were performed through straight lateral approach (Table 2).

Table 2

Surgical features of THA in patients with dislocations of C1 and C2 types according to Hartofilakidis classification

Criteria	Group		*p* value
	C1	C2	
Shortening osteotomy, *n* (%)	165 (50.6)	235 (100)	<0.001
Slide osteotomy or subtrochanteric osteotomy of femur, *n* (%)	17 (5.2)	0	<0.001
Standard approach, *n* (%)	144 (44.2)	0	<0.001
Positioning of the cup into the true acetabulum area, *n* (%)	225 (69.0)	233 (99.1)	<0.001
High position of cup, *n* (%)	101 (31.0)	2 (0.9)	<0.001
Cranial displacement of rotation center, average (min-max), mm	2.6 (0–30)	0.05 (0–7)	<0.001
Lateral under-coverage of the cup, average (min-max), % *	14.7 (0–44)	8.6 (0–35)	0.038
Bone grafting by autologous femoral head, *n* (%)	18 (5.5)	3 (1.3)	0.009
Length of osteotomized fragment of the greater trochanter, average (min-max), mm	62.5 (39–86)	78.6 (39–120)	<0.001
Contact area of the greater trochanter and femur, average (min-max), mm	28.5 (12–54)	44.6 (19–66)	<0.001
Contact degree of the greater trochanter (length of segment to length of contact area), average (min-max), %	47.1 (24–76)	56.7 (30–96)	<0.001
Lengthening of the leg during surgery, average (min-max), mm	25.3 (12–35)	28.9 (18–34)	0.723
Standard fixation of the greater trochanter, *n* (%)	99 из 165 (60.0)	218 (92.8)	<0.001
Nonstandard fixation, *n* (%)	66 из 165 (40.0)	17 (7.2)	<0.001
Use of trochanteric plate, *n* (%)	7 из 165 (4.2%)	1 (0.4%)	<0.008
Use of dysplastic femoral components, Wagner Cone type, *n* (%)	106 (32.5)	228 (97.0)	<0.001
Use of acetabular components of 44-46 mm in diameter, *n* (%)	189 (58.0)	225 (95.7)	<0.001
Total hip joints, *n* (%)	326 (100)	235 (100)	–

* Tikhilov R., Shubnyakov I., Burns S., Shabrov N., Kuzin A., Mazurenko A., Denisov A. Experimental study of the installation acetabular component with uncoverage in arthroplasty patients with severe developmental hip dysplasia. *Int Orthop.* 2016;40(8):1595-1599. doi: 10.1007/s00264-015-2951-z.

Acetabular component was implanted into the true cavity in 99.1% of cases in C2 subtypes and only in 69.0% of C1 cases ($p<0.001$). Cranial displacement of rotation center in patients with C2 subtype was reported only in two cases below 7 mm and with C1 subtype in 101 (31.0%) patients, and the mean displacement value with C1 was only 2.6 mm but in single cases amounted to 3 cm. Lateral under-coverage of acetabular component in patients with C2 subtype varied from 0 to 35% with average of 8.6%, and only in three cases bone grafting was performed by autologous femoral head. In patients with C1 subtype average under-coverage was 14.7%, and in 18 cases exceeded 30% which required bone grafting by autologous femoral head ($p = 0.009$). In C2 subtype due to the presence of rudimentary acetabulum the authors used cups of 44-46 mm in 225 cases (95.7%), while in group of C1 such cups were used only in 189 (58.0%) of cases ($p<0.001$) (Table 2).

Due to a greater degree of shortening the length of osteotomized femoral fragment in C2 group was statistically greater and amounted to average of 78.6 mm in contrast to 62.5 mm in patients with C1 type. This provided a better contact area of the greater trochanter and in majority of cases allowed to use standard fixation technique — cerclage wires and two screws. In C1 group of patients this fixation method was feasible only in 99 out of 165 (60.0%) patients, in remaining cases other fixation techniques were applied including 7 (4.2%) cases where trochanteric plate was used for secondary indications (Table 2).

In C2 group the need for deep positioning of the stem into an extremely narrow femoral canal required application of dysplastic Wagner Cone type components in 97,0% of procedures, while standard femoral components were implanted only in 7 (3.0%) of cases, while in C1 group conical stems for primary arthroplasty were used only in 106 cases (32.5%), so odds ratio for use of conical components in C2 as compared to C1 was OR = 67.601 (95% CI from 30.773 to 148.504, $p<0.001$).

Overall average time of arthroplasty was 118 min (95% CI from 115 to 121, with high heterogeneity — min 55, and max 250 min), and average blood loss was 487 ml (95% CI from 445 to 528, min 50, a max 3400 ml). The authors observed statistically significant difference between patients with history of earlier joint surgeries and patients without prior surgeries — 133 min (95% CI from 122 to 143) and 114 min (95% CI from 111 to 117) respectively ($p<0.01$), however, no statistically significant differences were reported between C1 and C2 groups in respect of time of surgery and volume of blood loss — $p = 0.644$ and $p = 0.111$, respectively.

Surgery without shortening osteotomy took slightly less time — 115 min (95% CI from 105 to 126 min) in contrast to 122 min (95% CI from 115 to 129 min), $p = 0.07$, but the blood loss volume was higher in average — 576 ml (95% CI from 437 to 715 ml) in contrast to 419 ml (95% CI from 357 to 481 ml), $p = 0.02$.

THA outcomes in patients with various types of high hip dislocation

Functional status of the patients reflected by Harris Hip score improved in average from 39.5 to 83.6 without statistically significant differences between C1 and C2. Somewhat higher Harris Hip scores were reported postoperatively in patients group with C1 without shortening osteotomy as compared to group with osteotomy — 84.7 and 79.9, respectively, but the mentioned differences were not statistically significant.

Early complications included 9 (1.6%) dislocations, 8 (1.4%) cases of femoral nerve neuropathy and 3 (0.5%) early infection. No cases of sciatic nerve paresis were observed. Re-fixations due to non-union of the greater trochanter were performed in 27 (6.8%) patients, in other 6 patients non-union of the greater trochanter was not accompanied by pain syndrome and patients are continuously followed up.

Revisions in the present group of patients were performed in 22 (3.9%) cases — 3 due to early infection, one due to late infection 6.5 years postoperatively, 2 due to stem loosening, 11 due to acetabular component loosening and remaining 5 due to recurrent or irreducible dislocations, one of those occurred in 11 years postoperatively due to breakage of polyethylene inlay along with its wear (Table 3).

Table 3

Complications and revision rate in dislocations of C1 and C2 types by Hartofilakidis classification

Description	Group		*p* value	Total
	C1	C2		
Complications				
Non-union of the greater trochanter, *n* (%)	14 из 165 (8.5%)	19 (8.1%)	0.887	33 (8.4%)
Dislocations, *n* (%)	5 (1.5%)	4 (1.7%)	0.876	9 (1.6%)
Infection, *n* (%)	1 (0.3%)	2 (0.8%)	0.384	3 (0.5%)
Early aseptic cup loosening (within 2 years), *n* (%)	1 (0.3%)	2 (0.8%)	0.384	3 (0.5%)
Femoral nerve neuropathy, *n* (%)	4 (1.2%)	4 (1.7%)	0.64	8 (1.4%)
Total, *n* (%)	25 (7.7%)	31 (13.2%)	0.032	56 (10.0%)
Revisions				
Revision due to deep infection, *n* (%)	2 (0.6%)	2 (0.8%)	0.742	4 (0.7%)
Revision due to acetabular component loosening, *n* (%)	3 (0.9%)	8 (3.4%)	0.037	11 (1.9%)
Revision due to femoral component loosening, *n* (%)	1 (0.3%)	1 (0.4%)	0.816	2 (0.3%)
Revision due to recurrent or irreducible dislocations, *n* (%)	3 (0.9%)	2 (0.8%)	0.932	5 (0.9%)
Total, *n* (%)	9 (2.8%)	13 (5.5%)	0.096	22 (3.9%)

Discussion

High hip dislocation in adults is a rare pathology in the developed countries thanks to ubiquitous newborns screening allowing to eliminate the issue at an early stage by conservative or surgical methods. At the same time there are endemic regions where the prevalence rate of the present congenital pathology is many times higher statistical averages and remoteness of large medical centers prevents timely diagnosis and results in an excess of the number of such cases in the population and increases their share in the structure of primary hip arthroplasty. According to the hip joint register of Vreden Research Institute the highest share of high hip dislocation in the structure of primary arthroplasty is observed in patients from North Caucasian region [27].

The issues of high hip dislocation is rather actively discussed in the specialized literature though the number of patients is usually limited to twenty-thirty cases [14, 17, 18, 28, 29] excluding meta-analyses [30], and with that all patients are pooled into a single Crowe IV type in the majority of publications. This classification is actively used by surgeons but it reflects only the degree of head displacement against the true acetabulum. Accordingly Crowe IV type is only the complete dislocation leaving the open questions, such as height of head displacement, presence or absence of supraacetabular osteophyte, shape of femoral canal. Thus it remains unclear is there a need for shortening osteotomy or is it possible to make cranial transfer of acetabular component which would allow only insignificant lengthening of the limb?

The present research demonstrates that the group of patients with high hip dislocation is extremely heterogeneous in intensity of anatomical alterations. Degree of proximal displacement of the femoral head can vary more than twice — from 29 to 78 mm. Contact of the femoral head with the iliac bone can result in formation of thickened bone site as well as in formation of a marked false acetabulum which can be a full-fledged bed for prosthesis cup. Finally, proximal femur can look like either as an under-developed tube with a narrow canal and rudiments of head and neck or as a normal femoral bone with normally sized canal, neck and head. The above anatomical diversity produces variety of treatment options and substantial differences in outcomes which in addition are related to minor case series.

Naturally there are significantly more detailed classifications like M. Gaston et al [20] but those are more descriptive rather than guiding in selection of surgical tactics, so are not widespread in the clinical practice. In the authors' opinion simple division of high hip dislocations for C1 and C2 types suggested by G. Hartofilakidis et al had a good clinical reason due to considering peculiar anatomical relations between femoral head and acetabulum which, as a matter of fact, defines the procedure specifics.

C2 type manifests by only the rudimental true acetabulum while femoral head is placed in the soft tissues without any contact with the bone. The surgeon has only one option to correctly position acetabular component, namely into the true acetabulum. C1 type features two acetabular cavities — true one filled with adipose tissue and false the latter is in contact with femoral head. The locations of true and false cavities can highly vary due to location of the femoral head, so C1 type can look even like Crowe III on x-rays but in reality it is a full dislocation with no contact between femoral head and true acetabulum (Fig. 5) [31].

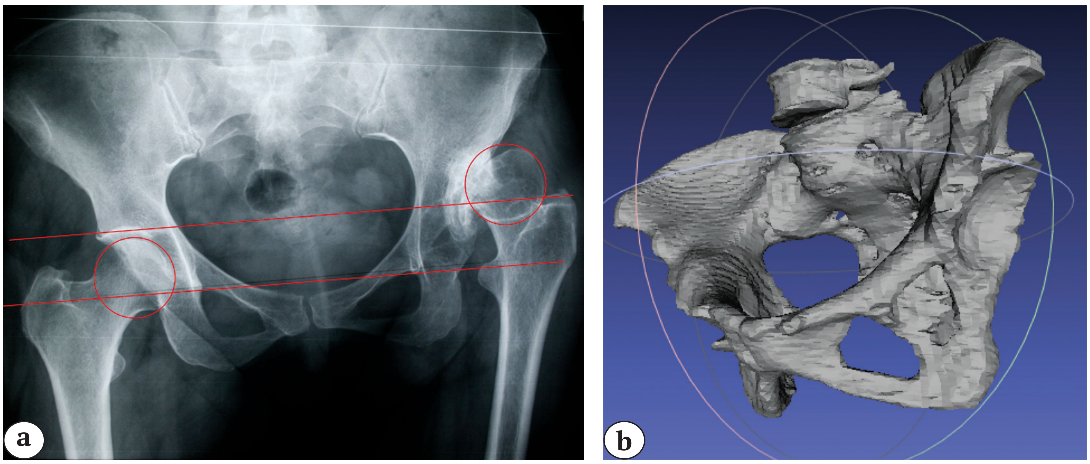


Fig. 5. Overall pelvis X-ray — femoral head is displaced cranially approximately at 75% of its height (a), correspondingly, it's Crowe III type, however, 3D reconstruction of CT views demonstrates complete dislocation of the femoral head (Crowe IV or C2 type by Hartofilakidis) — true and false cavities have no common space (b)

In this case, the anatomical position of cup is also preferred, however available sufficient supraacetabular bone stock, being an osteophyte or a false acetabulum, allows cranial transfer of the cup without loss of fixation stability.

Literature describes many options for hip arthroplasty in high hip dislocation. The majority of international authors stand for shortening osteotomy with a simultaneous prosthesis implantation [10, 12, 13, 14, 15, 24, 30]. But there are some papers evidencing possible joint replacement without osteotomy but with cranial transfer of the rotation center [17, 18]. Russian language literature includes methods of two stage treatment with femoral neck osteotomy at the first stage with lengthening of the limb for some period of time in external apparatus or by skeletal traction, and implanting of final prosthesis in a second stage [5, 16]. There are also publications advocating cup insertion into the false acetabulum to avoid excessive limb lengthening [16, 32]. Such procedure can be successful but in case of cup loosening the need arises for removal of well fixed stem due to impossible lowering of the leg up to the required height during insertion of revision cup close to the true center of rotation [26, 33]. Availability of only a rudimental acetabulum in C2 type requires use of very small size cups — 44-46 mm — in almost 96% of cases, which demands a compromise solution, namely use of a very thin polyethylene inlay with 28 mm head or use of a very small head (22-26 mm) in combination with a thicker inlay. Second option along with shortening osteotomy significantly increases the dislocation risk, so in our practice we used only 28 mm heads. In C1 type, in contrast, such size of cups was used only in 58% of cases, and odds ratio for use of smaller cups in C2 as compared to C1 was OR = 16.310 (95% CI from 8.341 to 31.889; $p<0.001$).

Functional outcomes of hip arthroplasty presented in the literature are significantly worse, as in the present research, than after standard primary replacement. This is accounted for by complexity of the surgery as well as by systemic skeletal changes — bone deformities of the lower limbs, valgus knee deformities, long term misbalanced spine-pelvic relations [4, 11, 18, 29, 34].

In the present study revision rate in the mid-term follow up of 6 years was only 3,9% which is slightly above the average for corresponding age group. However, if we add the complications rate and rate of revisions for fixation of the greater trochanter, the overall number of possible issues becomes substantial. So we can't evaluate the scope of the problem only basing on the survival rate of the prosthesis.

Can we assume in this case that the bigger share of the failure is related to the surgical method? Available literature demonstrates that the majority of researchers prefer various types of subtrochanteric osteotomies considering those a priori a more proper surgical option [7, 12, 14], but we did not find any publications comparing outcomes of subtrochanteric and Paavilainen osteotomies. At the same time there are much less papers presenting outcomes of proximal osteotomy with transfer of the greater trochanter (Paavilainen) but those also report high efficiency [13, 15, 25, 35]. Interesting is the fact that antagonists of Paavilainen osteotomy usually report high complication rate related to non-union and usually they are basing on the data of above mentioned publications but reporting similar level of observed complications peculiar to subtrochanteric osteotomy [12, 28]. Among the reviewed publications only two series included over 70 cases of subtrochanteric osteotomies [9, 36] while the first report of T. Paavilainen et al summarized their experience of more than a hundred of procedures [35].

None the less the issue of non-union of the greater trochanter is the key after shortening Paavilainen osteotomy. The present research demonstrates that despite the statistically significant higher average contact area between the greater trochanter and femur in C2, the non-union rate was practically not different in group with various dislocation types. Probably some mix factors that can't be adequately evaluated seriously impact the non-union rate — bone fragments congruity at the contact area, fixation strength, bone perfusion, load place by the patient on the leg, etc. Besides in the present series of cases the authors used standard fixation technique only in 83.2% of cases (467 joints) and other techniques in almost 17% of cases. Overall, the impression is that the length of greater trochanter coverage is important but in our practice when possible trochanteric plate was used to fix bone fragments in cases of evident limited bony contact. At the same time the authors observed trochanter non-union in C2 when contact area was over 60 mm (over 75% of bone fragment length) and three screws were used for fixation. It's possible that significant damage to endosteal perfusion was the reason for non-union after extreme treatment of the bone by conical reamers due to very narrow canal.

Understanding of the substantial anatomical differences between C1 and C2 types of high hip dislocation can be considered the key result of the present research. Along with similar complication rate and comparable revision rate in this case the surgeons face different issues. The major difficulty in C2 type is secure fixation of the acetabular component. Rudimentary acetabulum demands the use of minimal diameter cups and often fixation is gained by supplementary screws insertion but not to press-fit effect. Besides it's impossible to ensure a more reliable fixation by cranial transfer of the rotation center. The above mentioned in combination with poorer bone quality resulted to cup loosening in rather early term in 8 (3.4%) patients. Odds ratio for aseptic cup loosening in mid-term of 5.5 years in C2 type as compared to C1 was OR = 3.794 (95% CI from 0.996 to 14.458, p = 0.037). It's likely that longer follow up will reveal proportionally growing number of aseptic loosening cases. During past three years we started to use 3D printed custom made cups with iliac flange in patients of elderly age with severe osteoporosis of the acetabulum. Marked cranial displacement of the femur, on the other hand, allows to isolate a rather long fragment of the greater trochanter which can easily been translocated to lateral surface of the femur. Wire cerclage and two screws insertion usually present no problems for the surgeon but extremely narrow femoral canal and respectively poorer endosteal perfusion can prevent complete healing the osteotomized fragment of the greater trochanter with the femur at the osteotomy site.

C1 in its turn presents two arthroplasty scenarios. With moderate shortening and supraacetabular osteophyte surgeons can avoid shortening osteotomy, thus decreasing surgery time but necessitating cranial transfer of the rotation center. 2.5 cm is the limiting value for us but the current visualization and prototyping techniques allow to take patient specific decisions, precisely assess the contact area between implant and bone, and to optimize screws position. Another scenario stipulates also the use of shortening osteotomy and cup implantation close to the true rotation center, but in this case the length of osteotomized fragment of the greater trochanter is much less and bone osteophytes that tension soft tissues complicate bringing down the greater trochanter thus limiting its contact with the femur. In such a situation the surgeon should be ready to use a special plate to fix the greater trochanter. The odds ratio for use of trochanteric plate for primary indications in C1 as compared to C2 was OR = 10.367 (95% CI from 1.263 to 85.086, p = 0.008).

So, high hip dislocation of C2 type in all cases supposes shortening femur osteotomy, anatomical positioning of a small size acetabular component, rather easy bringing down of the greater trochanter with a possibility to fix it by two screws and cerclage.

In C1 type the expectancy to perform shortening osteotomy is 50%, of cranial transfer of the acetabular component — 31%, and complicated bringing down the greater trochanter followed by non-standard fixation options — 40%. Division of all cases into two types of high hip dislocation by the anatomical features will allow the surgeon to be more conscious in selecting the procedure, to minimize the errors and to obtain more predictable treatment outcomes.

Publication ethics

All patients provided informed consent to publication of clinical cases.

Competing interests: the authors declare that there are no competing interests.

Funding: state budgetary funding.

Authors' contribution

Tikhilov R.M. — development of study concept and design, interpretation and analysis of the data, editing.

Shubnyakov I.I. — coordination of researchers, interpretation and analysis of the data, statistical processing of the data, preparing text of the publication

Denisov A.O. — analysis and interpretation of obtained data, editing.

Pliev D.G. — analysis and interpretation of obtained data, editing.

Shubnyakov M.I. — collection and processing of the data, conducting research, statistical processing of the data, preparing text of the publication.

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