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ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

Dislocation after primary unilateral total hip arthroplasty – hip geometry and risk factors (a matched cohort analysis)

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SUMMARY
Introduction/Objective The purpose of this study was to determine if patient-related factors, such as hospitalization length and preoperative use of walking aids, and geometrical factors, measured with antero-posterior radiographs of hip, affect the risk of hip dislocation after total hip arthroplasty.
Methods A total of 36 of 433 (8.31%) patients with hip dislocation were identified in the institutional registry during a two-year period. The data for patients with and without hip dislocation were matched and compared.
Results Hip dislocation more often occurred in patients who had used walking aids before the operation compared to the ones who had not ($p < 0.001$). Also, a difference in the number of hip dislocations was noticed between the patients who stayed longer in the hospital after THA ($p < 0.001$). The patients with higher acetabular inclination angle ($p < 0.005$) and height of greater trochanter ($p < 0.001$) on radiographs had been more prone to hip dislocation. In addition to this, the "safe-zone" was not identified in our study ($p > 0.005$).
Conclusion Several factors which influence hip dislocation were identified in this study: patient characteristics and radiograph characteristics. Both groups of factors require attention and monitoring in future studies.
Keywords: hip dislocation; biomechanics; total hip arthroplasty, complications; "safe zone"

INTRODUCTION

Total hip arthroplasty (THA) is an effective, common and costly operation [1]. It is considered the most successful procedure in orthopedic surgery since it relieves pain, increases mobility and quality of life, and provides a high level of patient survival [2]. Despite the efficacy of THA, hip dislocation (HD) represents a major problem after THA [2, 3]. The annual rate of HD after primary THA was reported to be 0.1–10%, while revision due to HD dislocation was reported to represent 9–26% of all revisions of primary THAs [3, 4, 5].

Multiple factors have been suggested to contribute to HD [3, 6, 7]. Operation-specific risk factors include the hospital volume, surgeon's experience, surgical approach, suboptimal positioning of the acetabular and femoral component, soft-tissue imbalance, etc. [5, 7]. As the procedure-specific factors, acetabular cup diameter, femoral head diameter, femoral neck length, head-to-cup ratio, procedure type, and the use of a liner were analyzed [8]. Although treatment outcome highly depends on the quality of surgical reconstruction of anatomical and biomechanical relations of the bone tissue [3], HD was noticed to occur even in the absence of procedure-specific mistakes. Thus, patient-specific risk factors for HD, including advanced age, high body mass index, comorbidities (especially psychiatric and neurologic diseases), low physical activity level, preoperative use of walking aids (PUWA), impaired compliance (failure to comply to permitted activities after surgery), and absence of exercise therapy, were suggested as important [7, 9, 10, 11]. According to the most recent studies, the length of stay (LOS) after THA has been shortened [4, 7, 8]. Out of many different patients' and providers' characteristics that determine LOS, comorbidity is the most documented one [12, 13]. It is also known that early mobilization results in the reduction of LOS and cost outcomes [14].

Despite the number of researches done, the risk factors of HD are not yet fully understood [1, 15]. Recent studies examine the influence of factors such as alcohol consumption, some diseases, and postoperative activity restrictions, but also the existence of the safe zone for cup

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position in HD occurrence [6]. The main limitation of the majority of published studies are the following: a small number of risk factors were analyzed, they failed to report the data on functional abilities of patients before and after the surgery, did not provide a description of procedures used in physical rehabilitation, did not perform long-term follow up of patients, etc.

The main aim of our study was to assess the link between patient-related factors and hip geometry related to the incidence of HD after THA.

METHODS

Patients

This clinical monocentric study was performed by prospectively gathering data on 433 patients that were subjected to THA between January 2016 and December 2017. Some patients were surgically operated due to nontraumatic indications, while others needed urgent surgery due to traumatic indications. Oral and written informed consent was obtained from all patients. The study was done in accordance with the institutional committee on ethics.

By analyzing hospital records, we identified 36 patients who experienced HD after THA. HD was identified as an episode that required closed or open reduction of a THA prosthesis. In cases of multiple HD, only the first occurrence was evaluated. Since radiographs of two HD patients were not adequate for analysis (there was no visible lesser trochanter and iliac crest), these two HD patients were excluded from the analysis, which resulted in a total of 34 HD patients. The control group consisted of 34 patients, operated on during the same period and under the same conditions, who did not experience HD after THA. The controls were matched to HD patients, using basic patient characteristics: age at the time of primary THA (± 3 years), sex, etiology responsible for THA (traumatology/nontraumatology), type of prosthesis (exact), comorbidities (Charlson Comorbidity Score), and physical activity level before the operation. The exclusion criteria were evidence of infections, malignant disease, instability, THA revision, other major joint arthroplasty or orthopedic surgery on the lower extremity one year before THA. Patients included in the study were followed-up for six months.

Surgical protocol

The patients were operated on by 13 surgeons, 10 of whom had 5–25 years of experience, and three of whom less than five years of experience. All the patients were operated on according to the protocol of the Clinical Center, which requires the surgery to be done under general anesthesia and posterior approach, without reconstruction of the external rotators. Out of 433 patients a total of 100 patients received cement type of prosthesis (patients older than 65); cement type prosthesis was received by seven HD patients and nine controls. Patients younger than 65 received a noncement (total n = 240, 17 HD patients, and 17 controls) and hybrid (total n = 93, 10 HD patients, and eight controls) type of prosthesis. The choice of prosthesis components and prosthesis size were at the discretion of the attending surgeon. Different designs (Implancast, DePuy, Zimmer, Stryker, Zimmer/Biomet) of cup/stem and femoral head sizes (28 or 32 mm) were used. The bearing surface for all prostheses was polyethylene on metal. In patients with a noncement and hybrid type of prosthesis, a head-on-polyethylene liner was used.

Postoperative protocol

During hospitalization, all the patients had physical therapy according to the standard protocol. The patients were verticalized immediately after the intervention, walked on crutches, with or without load-bearing on the leg that was operated on, depending on the type of THA and the surgeon's opinion. Physiotherapy took place daily, except on weekends. General postoperative restrictions for the first three months were used.

Patient and implant characteristics

Baseline patients' data included age at the time of primary THA, sex, THA side, comorbidities, physical activity level, and etiology (diagnosis responsible for THA). We used the Charlson index by defining the 19 comorbid conditions [16]. In addition to the Charlson score, individual comorbidities were included for separate analysis, consisting of diabetes mellitus, rheumatoid arthritis, peripheral vascular disease, neurologic disease, pharmacologically treated psychiatric disease and consummation of more than two units of alcohol daily. Physical activity level, according to Devane et al. [17], was quantified as the level 0–5.

Pre/postoperative data included analysis of mechanisms and time of dislocation, PUWA, LOS in hospital after surgery, and implementation of exercise therapy before and after THA. The patients were asked about any trauma or motions that led to the HD, if event represented the first or recurrent dislocation, how long ago the primary THA was performed, and whether they were subjected to physical and exercise therapy.

Operative notes were used to identify the operative side, surgeon, implant type, cup size, and femoral implant diameter.

Measurement of radiographic variables was performed using standard anteroposterior radiographs made immediately after THA. Measurements were performed by two independent authors, twice for each radiograph. The mean value of the four measurements was used for analysis. The reconstruction of the hip rotation center was performed by drawing a circle around the femoral head. Köhler line was drawn along the medial aspect of the ilium and ischium. First, a line through the base of the acetabular teardrop was drawn (Line 1). Then, a Köhler line was drawn from the lateral border of the sciatic notch to the medial border of the obturator foramen. Finally, a line was drawn through the center of the femoral head to the iliac crest (Line 2). The acetabular teardrop was used, as a reference since it

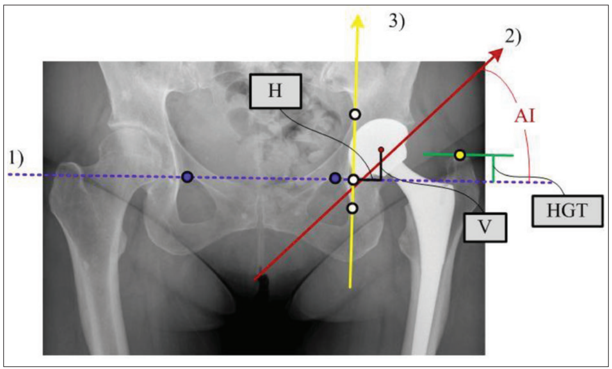

Figure 1. Representation of radiographic measurement parameters; Line 1 – horizontal; Line 2 – for AI determination; Line 3 – Köhler line; AI – acetabular inclination; HGT – height of greater trochanter; V – vertical offset; H – horizontal offset

represents an accurate method to measure distances [12, 15]. The lateral lip of teardrop indicates the exterior acetabular wall. Cup position was assessed according to the acetabular abduction angle (the angle between Line 1 and Line 2), vertical offset and the horizontal offset. Vertical offset was measured from the center of the femoral head to Line 1. The horizontal offset was measured from the center of the femoral head to the Köhler line (normal). The radiographic reconstruction of the abductor mechanism was measured using the height of the greater trochanter (HGT) as the distance between the Line 1 and the parallel line crossing the tip of the greater trochanter (Figure 1).

Statistics

The study data were analyzed by descriptive statistics and presented in tables. The mean value was used as a measure of central tendency and standard deviation as a measure of dispersion for continuous variables. The values of categorical variables were presented as rates or percentages. The normality of data distribution was tested by the Kolmogorov–Smirnov test. A χ^2 test was used to assess the difference in the distribution of categorical data between the HD group and the control group. Student's t-test or Mann–Whitney test was used to assess differences in mean values of interval data. Statistical analysis was performed in SPSS Statistics, Version 20.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Out of 433 patients, 36 patients experienced HD, representing a rate of 8.31%. Thirty-three HD patients were stable after non-operative treatment, while three HD patients needed a revision. Out of 36 HD patients, two were excluded from the analysis, due to technical problems with radiographs.

HD patients and control patients did not significantly differ regarding their age, side that was operated on, THA etiology, Charlson comorbidity score, neither were individual comorbidities more frequent in HD patients. Also, physical activity levels were similar in HD and control patients.

Table 1. Basic patient data

Parameter	HD patients	Control patients	p
Age (X ± SD)	66.05 ± 10.22	64.79 ± 9.85	$p > 0.05^a$
Sex (n)			
Male	10	10	$p > 0.05^b$
Female	24	24	
THA side (n)			
Left	13	16	$p > 0.05^b$
Right	21	18	
THA etiology			
Primary OA	17	20	$p > 0.05^b$
Congenital hip disorder	1	2	
Rheumatologic disorders	0	1	
Trauma	12	8	
Avascular necrosis	3	1	
Metabolic bone disorders	1	1	
Other	0	1	
Charlson comorbidity score			
0	1	3	$p > 0.05^b$
1	1	2	
2	4	6	
3	7	9	
4	7	7	
5	5	2	
6	3	3	
7	4	1	
8	2	1	
Individual comorbidities (n)			
Neurological diseases	2	1	$p > 0.05^b$
Diabetes mellitus	3	4	
Psychiatric diseases	6	1	
Vascular diseases	3	1	
Rheumatoid arthritis	0	2	
Alcohol consumption	1	0	
Physical activity level			
0	0	0	$p > 0.05^b$
1	0	0	
2	6	7	
3	16	13	
4	11	11	
5	1	3	

THA – total hip arthroplasty; HD – hip dislocation;
[a]Mann–Whitney test;
[b]χ^2 test

There was no statistically significant difference in the occurrence of HD after THA if the patient was operated on by the surgeon with less or more experience ($p > 0.05$, χ^2 test). There was a similar number of patients receiving pre/postoperative rehabilitation treatment in both groups, but PUWA was more frequently used in HD patients compared to control patients. HD patients also spent significantly more time in hospital after THA. Time of dislocation in the HD group ranged 3–3300 days after THA (median 282.50), and the most frequent mechanism was inappropriate movement. Late dislocations (> 90 days after THA) were more frequent than the early ones.

HD patients and control patients did not significantly differ in acetabular shell size, cup anteversion angle, the

Table 2. Pre/post total hip arthroplasty-related data.

Parameter	HD patients	Control patients	p
PUWA (n)			
Yes	19	4	p < 0.001[b]
No	15	30	
LOS (days)	11.00 ± 2.71	8.82 ± 1.66	p < 0.001[a]
Rehabilitation (n)			
Preoperative (Yes/No)	17/17	14/20	p > 0.05[b]
Early postoperative (Yes/No)	34/0	34/0	
Post THA (Yes/No)	11/23	14/20	
HD mechanism			
Falls	5	/	p < 0.001[b]
Inappropriate movement	11		
Sitting	3		
Bending	5		
Squatting	1		
Unknown	9		
Time of dislocation (n)			
Early/Late	14/20	/	p < 0.001[b]

THA – total hip arthroplasty; HD – hip dislocation; PUWA – preoperative use of walking aids; LOS – length of stay;
[a]Mann–Whitney test;
[b]χ^2 test

Table 3. Implant and radiographic data

Parameter	HD patients	Control patients	p
Acetabular shell size (mm)	51.08 ± 13.90	53.61 ± 3.77	p > 0.05[a]
Femoral head size (mm)			
28 mm	18	13	p > 0.05[b]
32 mm	16	21	
Acetabular inclination (degrees)	47.52 ± 6.07	45.18 ± 2.98	p < 0.05[c]
Horizontal offset(mm)	31.00 ± 4.85	29.22 ± 3.07	p > 0.05[a]
Vertical offset (mm)	22.50 ± 6.11	23.06 ± 5.69	p > 0.05[a]
Height of greater trochanter (mm)	2.27 ± 2.88	0.46 ± 1.30	p < 0.01[a]
Cup position			
Inside safe zone[d]	3	2	p > 0.05[b]
Outside safe zone[d]	21	32	
Abductor mechanism			
Inside safe zone[d]	2	1	p > 0.05[b]
Outside safe zone[d]	32	33	

HD – hip dislocation;
[a]Mann–Whitney test;
[b]χ^2 test;
[c]Student's t-test;
[d]safe zone defined as 40 ± 10 abduction, 15 ± 10 anteversion for cup for abductor mechanism

horizontal and vertical offset of a cup, nor the frequency of different femoral head sizes, cup position zone, and abductor mechanism zone. However, HD patients had significantly higher acetabular inclination angle and height of greater trochanter when compared to control patients.

DISCUSSION

HD remains the major complication after THA. While multiple reasons may be contributing factors leading to dislocation, precise identification of the exact reason is of major importance. As with any multifactorial problem, the prediction of postoperative outcomes is difficult. The results of our study have shown that LOS, PUWA and acetabular inclination and HGT are associated with the occurrence of HD.

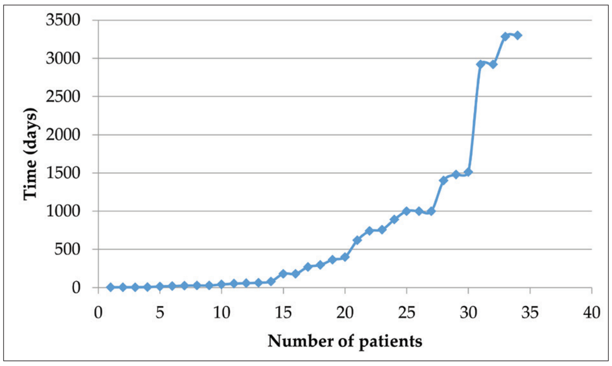

Figure 2. Time of occurrence of hip dislocation

Understanding the factors associated with the occurrence of HD can help plan the operation, preventing the occurrence of HD and reducing treatment costs [3, 4, 10, 18, 19]. Since the Republic of Serbia does not have a national register of patients with THA, we used systematically collected data from our medical center.

In most of the previous studies, it was shown that many factors are associated with HD, but these studies predominantly investigated surgical factors, which were not in the focus of our research [18]. In our medical center, all surgeons use a posterior approach, the same type of prosthesis, and the same operating technique.

The main purpose of this study was to assess the patient-related factors and radiological factors on HD occurrence after THA.

HD is a significant problem in clinical practice [3, 4, 19]. Restoration of the native anatomy plays a crucial role in preventing instability [6]. Malposition of the acetabular component is associated with the occurrence of many complications, not only HD [20]. Some authors still accept some kind of "safe zone" for prosthesis placement [1, 4, 10], while others question whether it exists [6, 15].

Cup position with an inclination/abduction of 40° ± 10° and an anteversion of 10–20°, the so-called "safe zone" to avoid HD, is internationally considered desirable and used in clinical practice. However, experience showed that components positioned in this zone can and do dislocate [4]. This was confirmed by HD occurrence even after the use of computer-assisted surgery during THA [20]. As mentioned before, some authors argue that the "safe zone" does not exist or that it is different for each patient [6, 12]. Also, some authors claim that the "safe zone" depends on the operative approach or some other factor [20].

Hip geometrical parameters have been suggested as important factors in the evaluation of the risk of HD [3, 4, 10, 19]. Our results show that patients who experienced HD had the higher acetabular inclination and lower height of greater trochanter. Previous studies have shown that the height of the great trochanter depends on the soft tissue reparation and thigh muscle strength [1, 20]. Also, cup position was not significantly different between study groups, which aligned with findings of Esposito et al. [6]. This indicates that muscle strength is of great importance in the prevention of HD [14].

There is no consensus in literature data about optimal acetabular orientation since different referent systems, surgical techniques, and measurement techniques were used. The malposition of the acetabulum can lead to numerous complications among which is HD. This is explained by bigger bearing surface and instability [20].

The number of all observed HDs (n = 34, 8.31%) in our study is on the upper limit described in the literature (0.3–10%) [1, 3, 4]. If we follow only operatively treated HDs (three patients) frequency would be 0.69%. There are several factors such as the posterior operative approach, middle hospital volume, lack of surgeon experience, which could explain this high incidence of HD [4, 13]. Also, we included a wide range of patients in our study, even the patients with an increased risk for HD – older patients with cement prosthesis, posttraumatic THA, psychiatric patients, and patients with neuromuscular impairment. Older age is associated with a lack of coordination, senses and muscle weakness, comorbidity, poor compliance, and preference to falling. Abovementioned characteristics of older patients increase the risk of HD.

Data that come from national registers or multicentric studies took patients with "ideal" characteristics such as large femoral head, non-cement prosthesis, and numerous exclusion criteria [3, 19]. The advantage of our study was that we did not have a loss of patients because each patient treated in our hospital was adequately followed as there is no other hospital where HD could be treated.

Another potential risk factor for HD is the so-called early mobilization regimen of physical therapy [21]. Every patient in our medical center is subsided to early mobilization, so we were not able to evaluate it as a risk factor.

Surgeon experience and volume were not identified as significant factors for the occurrence of HD. All surgeons in our medical center had low patient volume.

Previous research showed that physiotherapy after THA enhanced postoperative recovery by promoting faster rehabilitation and improving functional outcomes [11, 21, 22]. It is argued that even though intensity and frequency of the ideal rehabilitation protocol are unknown, early multidisciplinary rehabilitation improves outcomes [11]. However, our results did not show that physiotherapy is a protective factor. The reason could be that physiotherapy is mandatory in our medical center for all patients after THA. Also, the number of patients included in our study could be insufficient to show the significance of physiotherapy.

The number of patients who suffered from HD is 14 in the first 90 days of surgery, and 20 patients after 90 days. Similar results were obtained in the study of Kunutsor et al. [3] where half of all HDs occurred in the first three months postoperatively.

LOS is an important component of the recovery and indicator of the overall cost after THA. Since the implementation of fast track surgery, there is a tendency to reduce the LOS in hospital to reduce costs, reduce the number and seriousness of complications, and increase the number of available hospital beds [13]. Every hospitalization longer than four days or 10 days is considered prolonged hospitalization [9, 22]. Shorter LOS is associated with better motivation and satisfaction of patients during recovery [9].

Some factors associated with longer LOS (age, sex, comorbidity, economic status, PUWA) are better documented than others (surgeon volume, infections, general anesthesia). High-quality studies should provide more evidence for the relationship between LOS and mentioned factors [21, 22].

Jørgensen et al. [7] showed that longer LOS could increase the risk of complications but not the risk of HD. On the other hand, shorter LOS does not mean more HDs [9], which is contradictory with findings of Mauerhan et al. [23]. In our study, LOS was 6–14 days, which is in line with other studies where a conventional surgical track regimen was used. Different treatment concept assumes a postoperative early mobilization program. Larger value of BMI is associated with longer LOS and increasing costs [24].

We showed that HD patients spent more time in hospital after THA and more frequently needed PUWA, which reflects their lower pre/post physical capabilities.

PUWA is associated with the occurrence of medical and non-medical complications [25]. PUWA is a sign of loss of hip muscle strength and in most cases is associated with older age and/or comorbidity [11]. Age over 70 years, female sex, depression, and BMI over 35 are highly associated with PUWA [22]. More research is needed to examine the impact of specific comorbidities on PUWA [25].

Results of our study showed that PUWA is a risk factor for HD which is aligned with the results of the study by Jørgensen et al. [25]. The impact of PUWA must be additionally confirmed in new studies.

There are several limitations to our study. The most significant one is that we investigated a three-dimensional problem by using two-dimensional X-ray images for measuring acetabular inclination. However, femoral anteversion was not measured. Also, we did not have access to the software made for the use of measuring these parameters. All investigated parameters were measured manually. The number of patients included in our study is relatively small and the follow-up period is short, compared to other studies. Limitations of our study also include loss of some radiographic data, the lack of detailed registration of patient compliance to restrictions and missing clinical information including the loss of BMI data, absence of detailed functional results of the THA according to a clinical scale.

CONSLUSION

HD is a serious complication that may be attributed to the multiple factors. Having in mind results presented in this study, we suggest implementation of PUWA, LOS, and hip geometry monitoring in addition to other well-known risk factors.

Conflict of interest: None declared.

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Дислокација после уградње примарне унилатералне тоталне ендопротезе кука – геометрија кука и фактори ризика (упарена кохортна студија)

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САЖЕТАК
Увод/Циљ Циљ истраживања је да утврди на који начин фактори као што су дужина постоперативне хоспитализације, употреба помагала за ходање пре операције као и геометријски фактори који су мерени на антеро-постериорном радиографском снимку утичу на ризик од настанка дислокације кука после тоталне ендопротезе кука.
Методе Коришћењем институционалног регистра током двогодишњег периода идентификовано је 36 болесника (8,31%) са дислокацијом кука, од укупно 433 болесника са тоталном ендопротезом кука.
Резултати Добијени подаци болесника са дислокацијом и без дисколације су упоређивани и анализирани. Дислокација кука била је чешћа код болесника који су пре операције користили помагала за кретање у односу на оне који нису ($p < 0{,}001$). Значајна разлика је регистрована код болесника код којих је хоспитализација после операције трајала дуже ($p < 0{,}001$). Болесници са већим углом инклинације ацетабулума ($p < 0{,}005$) и вишим великим трохантером ($p < 0{,}001$) на радиографским снимцима су чешће имали дислокацију. Поред тога, „сигурна зона“ у нашој студији није идентификована.
Закључак У овом истраживању индентификовни су фактори који су у вези са дислокацијом кука као што су дужина постоперативне хоспитализације и употреба помагала за ходање пре операције. Такође, идентификовани су и радиографски фактори, који заслужују даљу пажњу и праћење у будућим истраживањима
Кључне речи: дислокација кука; биомеханика; тотална артропластика кука, компликације; „сигурна зона“