THE INFLUENCE OF SPINOPELVIC RELATIONSHIPS ON LATE DISLOCATION OF THE PROSTHETIC FEMORAL HEAD AFTER TOTAL HIP ARTHROPLASTY

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Objective. To analyze the influence of sagittal balance parameters on the risk of dislocations of the head of the femoral component of the hip joint endoprosthesis.
Material and Methods. A retrospective analysis of medical records of 113 patients with idiopathic coxarthrosis who underwent unilateral total hip arthroplasty was performed. The study assessed the parameters characterizing the sagittal balance in patients without prosthetic femoral head dislocation in the postoperative period (Group 1; n = 60) and in patients treated for prosthetic femoral head dislocation (Group 2; n = 53). Comparison of indicators was carried out by non-parametric Mann — Whitney U-test, and identification of dislocation predictors — by building single- and multi-factor logistic regression models. Differences were considered statistically significant at the achieved significance level $p < 0.05$.
Results. In Group 1, the type 3 sagittal balance according to Roussouly prevailed (48 %), in Group 2 — types 1, 2 and 4 (75 %). In patients with types 1 and 2 sagittal balance, the dislocations of the prosthetic femoral head occured 1.84 times more often than in patients with type 3, and that in patients with type 4 — 1.66 times more often.
Conclusion. Patients with Roussouly type 3 sagittal balance have significantly lower risks of postoperative dislocation of the prosthetic femoral head, as compared with those with types 1, 2 and 4.
Key Words: coxarthrosis, total hip replacement, dislocation of the prosthetic femoral head, sagittal balance, pelvic tilt, hip-spine syndrome.
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The specifics of spinopelvic relationships that characterize the spatial position of the body in the sagittal plane are well studied in patients with spine diseases, including lumbar pain, spondylolisthesis and spinal deformities. In most patients, changes in the pelvic tilt (PT) angle caused by a change in body position do not have a significant effect on the position of the acetabular component of the endoprosthesis; however, individual differences can be quite pronounced. In case of a severe spinal deformity or high sagittal mobility of the pelvis, their influence on the spatial orientation of the acetabulum should be taken into account in order to ensure joint stability in different positions (lying on the back, standing and sitting), thereby reducing the likelihood of wear, as well as dislocation and loosening of the endoprosthesis. In such cases, prior to surgery, patients are advised to get X-rays of the lumbar spine and pelvis in different positions to assess the mobility of the spinopelvic complex, since patient-specific calculation of the anteversion of the acetabular component of the endoprosthesis enables to take into account the sum of the following factors: incidence of diseases and previous surgeries on the spine, spinopelvic mobility, age [1]. Based on this, it can be concluded that pelvic tilt caused by postural changes should be considered as one of the indicators in preoperative planning, especially in patients with high pelvic mobility.

The objective is to analyze the influence of sagittal balance specifics on the risk of dislocations of the femoral head of the hip joint endoprosthesis in the late (more than 6 months) postoperative period.

Material and Methods

Patients

The study included 113 patients with idiopathic unilateral (left/right) coxarthrosis who underwent total hip arthroplasty. A monocentric analysis was performed retrospectively based on the medical histories of patients treated in 2007–2021. In the course of the study, two groups were formed: Group 1 (control) included 60 patients without dislocation of the prosthetic femoral head, and Group 2 included 53 patients with dislocation.

Study inclusion criteria:

– unilateral idiopathic coxarthrosis, for which total hip arthroplasty was performed;

– total hip arthroplasty from the anterolateral approach;
– the full range of motion in the contralateral joint;
– the patient's physical status conforms to ASAII class according to the classification of the American Association of Anesthesiologists;
– postoperative X-ray images of the pelvis and lumbar spine, performed with the patient standing in the lateral projection, that allow to assess the sagittal balance parameters;
– each operating surgeon should have more than 8-year experience with at least 7 years of experience in using computer navigation and/or robotics;
– for Group 1 – a follow-up period of at least 3 years after hip arthroplasty;
– for Group 2 – dislocation of the prosthetic femoral head developed in a period from 6 months to up to 3 years after surgery.

Exclusion Criteria:
– bilateral coxarthrosis at the time of the study or limited range of motion, indication of dislocations, subluxations or pain in the area of the contralateral joint;
– the difference in the length of the lower limbs is more than 2 cm;
– installation of the acetabular component of the endoprosthesis outside the Lewinnek safe zone [2];
– malposition of the acetabular or femoral component of the endoprosthesis;
– dislocation, including traumatic, of the femoral component of the endoprosthesis, which occurred under a significant force (injuries, falls from height, etc.);
– history of periprosthetic infection;
– grade III obesity or more.

Zimmer (n = 30), DePuy (n = 47), Smith & Nephew (n = 14), ESI (n = 22) prostheses were used for arthroplasty, with the following head sizes of the femoral component of the endoprosthesis: in Group 1 without dislocation – 28 mm (n = 25), 32 mm (n = 23), 36 mm (n = 12), in Group 2 with dislocation — 28 mm (n = 27), 32 mm (n = 24), 36 mm (n = 2). According to selection criteria, in all patients, when installing the endoprosthesis, the rules for positioning the pelvic component according to the Lewinnek safe zone concept were observed.

Techniques

The groups were compared with each other based on the analysis of X-ray images performed after arthroplasty with stable verticalization of patients over a period from 6 months up to 3 years according to the following parameters: the angle of the sacrum slope in the standing position (SS), the magnitude of the global lumbar lordosis (GLL) in the standing position, the pelvic index (PI), the inclination angle of the acetabular component of the endoprosthesis (AI), the angle of anteversion of the acetabular component of the endoprosthesis in the standing position (AA), calculated according to Lewinnek, Liaw, Pradhan, and the type of sagittal balance (type of posture) according to Roussouly [3] (Fig. 1).

Methods for calculating sagittal balance indicators in conditions of a prosthetic hip joint correspond to those accepted in modern vertebrology (Fig. 2–4).

PI was calculated as the angle between the line drawn from the center of the bicoxofemoral line to the center of the S1 endplate, and perpendicular to the S1 endplate (Fig. 2).

The sacral slope (SS) in the sagittal plane on X-ray images was defined as the angle between the plane of the S1 superior endplate and the horizontal line (Fig. 3). The proper pelvic tilt was calculated using the formula: 0.5PI + 15°.

The magnitude of lumbar lordosis (GLL) was measured according to Cobb method between the upper endplates of L1 and S1 vertebral bodies (Fig. 4). The magnitude of the proper lumbar lordosis was calculated by the formula: GLL = PI + 9° [14].

Statistical analysis

The values of interval indicators (all except the type of spine according to Roussouly) were checked for normality using the Shapiro – Wilk test; the homogeneity of dispersions in the groups with and without dislocations was studied using the Fisher F-test. Due to the non-compliance with the necessary conditions of normality and homogeneity of dispersions for parametric tests, the indicators were compared using the non-parametric Mann – Whitney U-test. Interval indicators are presented as a median [first quartile; third quartile]: MED [Q1; Q3].

Spine type according to Roussouly was compared by two-tailed Fisher's exact test, with the number and percentage of group size given for each grade.

Dislocation predictors were identified by constructing single- and multi-factor logistic regression models.

Differences were considered statistically significant at $p < 0.05$.

Calculations and drawings were made in the RStudio program (version 1.4.1106© 2009–2021 RStudio, PBC) in the R language (version 4.0.5).

Results

The comparison groups turned out to be matched in terms of the age and sex structure: Group 1 included 60 patients (18 men and 42 women) aged 33–80 who did not have a dislocation of the femoral component of the endoprosthesis after surgery; Group 2 included 53 patients (17 men and 37 women) aged 31–86, in whom dislocation of the femoral component of the endoprosthesis was detected during the postoperative follow-up. Patients indicated insignificant daily physical activity accompanying the dislocation; in most patients, the dislocation occurred when standing up from a sitting position without additional external support.

80 % of patients suffered from grade I obesity, and 20 % of grade II obesity (without statistically significant differences between the groups on this indicator).

The results of the statistical comparative analysis between the two groups are presented in Table 1, models of logistic regression of dislocations – in Table 2.

According to the data obtained, type 3 of the sagittal balance according to Roussouly prevailed (48 %) among the patients from Group 1, with the lowest frequency of this type in Group 2 (24 %).

In patients with types 1 and 2 of the sagittal balance, the frequency of dislocations of the prosthetic femoral head occurred 1.84 times more often, and in patients with type 4 – 1.66 times more often compared to patients with type 3. Thus, by constructing single-factor logistic regression models, individual dislocation predictors for the femoral head of the endoprosthesis were identified: Roussouly sagittal balance in a type 3 patient ($p = 0.010$) reduces the chance of endoprosthesis dislocation by 0.35 times, while types 1, 2 and 4 are associated with an increased probability of dislocation (by 1.75 times).

An increase in the angle of inclination of the acetabular component of the endoprosthesis by n° is associated with increasing probability of dislocation by 1.05n times. An increase in the angle of anteversion, measured according to Lewinnek, by n° is associated with decreased probability of dislocation by 0.94n times.

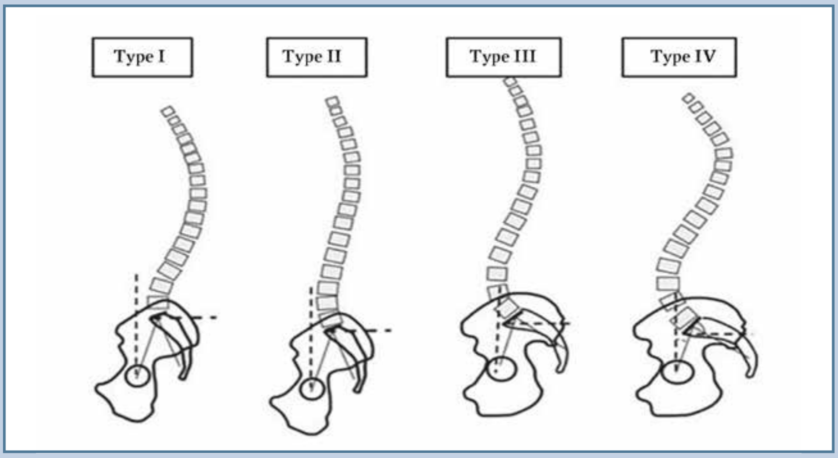

Fig. 1
Types of sagittal profile according to Roussouly [3]

Discussion

It is known that the value of anteversion of the acetabulum directly affects the stability of the joint and the lifespan of the endoprosthesis after total hip arthroplasty. However, the optimal value of anteversion of the acetabulum remains controversial [1]. Charnley et al. [4] state that the value of anteversion angle of the acetabulum should be 0°, Coventry et al. [5] – 15°, and Harris et al. [6] – 20°. In 1978, Lewinnek et al. [2] proposed the concept of a safe zone for the position

Fig. 2
Vertical lateral X-ray image of lumbosacral spine with pelvic index calculation

Fig. 3
Vertical X-ray image of lumbar spine in lateral projection with sacrum slope calculation

Fig. 4
Vertical X-ray image of lumbar spine in lateral projection with calculation of global lumbar lordosis

of the acetabular component of the endoprosthesis, which is determined by the value of anteversion angle of 15° ± 10° and the inclination angle of 40° ± 10°. According to Lewinnek et al. [2], the frequency of postoperative dislocations is 1.5 % if the position of the acetabular component of the endoprosthesis is in the safe zone, and increases to 6.1 % if it is outside this zone. The safe zone concept has been widely used in clinical practice to date.

Wang et al. [7] noted that in patients with ankylosing spondylitis, PT increases in the standing position, and pelvis deviates backward. After total hip arthroplasty, the angle of anteversion and the angle of inclination of the acetabular component go beyond the safe zone in 19.2% and 11.5 % of cases, respectively, but subsequent observations of patients did not reveal dislocation of the endoprosthesis.

Kobayashi et al. [8] reported three cases of hip dislocation after total hip arthroplasty in patients with an increased angle of anteversion of the acetabulum due to thoracolumbar kyphosis and excessive posterior pelvic tilt that occurs when standing up (in the standing position): thus, the dislocation could have occurred just from a small load on the prosthetic joint. After the surgery, when changing from a horizontal position on the back to a vertical position, pelvis strongly deviated backward, and the angle of anteversion of the acetabulum became too large, which led to an anterior dislocation of the head of the femoral component.

Pelvis inclination changes as the position of the body changes, which challenges the concept of a safe zone with the usual position of the acetabular component of the hip endoprosthesis [7]. The phenomenon of changing anteversion of the acetabulum with a change in pelvic tilt is a new challenge to the traditional safe zone concept. Lazennec et al. [9] suggested that the safe zone of the acetabular prosthesis was determined for the supine position. Most postoperative dislocations, however, occur when the patient is standing or sitting, which suggests that the prosthesis stability in the functional positions is critical.

McCollum et al. [11] suggested that the ideal value of anteversion angle should be 20–40° relative to the anterior plane of the pelvis. Nishihara et al. [12] believed that if the anteversion of the acetabulum is 20° in the supine position, then the hip joint prosthesis is relatively stable in the sitting position. Shon et al. [13] reported a single case when a patient developed dislocation after total hip arthroplasty, In this case, SS was 49°, and anteversion of the acetabulum was 26° in the supine position, in the standing position SS was 16° and anteversion of the acetabulum was 60°.

Understanding the relationship between the spine and pelvis is essential to achieving positive outcomes in total hip replacement. These relationships become significantly more complicated with a spine or hip joint pathology, a combination of these pathologies, or a change in body position. This fact must be taken into account in preoperative planning. Studies by colleagues from Russia and other countries show that the optimal position of the acetabular component of the endoprosthesis in each case depends both on the balance of the sagittal profile and on the mobility of the spinopelvic complex [15]. Despite the fact that there are studies that made attempts to analyze close relationship between spine and pelvis, including in combination with congenital pathology of the hip joint [9, 16–22], none of them took into account the influence of the posture type according to Roussouly on the position of the acetabular component of the endoprosthesis and, respectively, on the frequency of postoperative dislocations of the head of the femoral component after total hip arthroplasty.

Our retrospective study found that patients with Roussouly type 3 had a significantly lower risk of postoperative dislocation of the femoral head compared with types 1, 2, and 4, where the risks of prosthesis dislocation were significantly higher (in 1.75 times). This allows paying attention to this factor at the stage of preoperative examination as a potential predictor of a possible postoperative complication. In our opinion, already at this stage, patients can be assessed by the type of posture. In patients with Roussouly type 3, the acetabular component of the endoprosthesis should be placed within the Lewinnek safe zone, patients with types 1, 2, and 4 require additional examination to determine the optimal orientation of the implantable acetabular component. In this case, it is necessary to take into account not only the existing type of posture according to Roussouly, but also the degree of mobility of the lumbar, lumbosacral spine and pelvis as a whole. To do this, patients with types 1, 2, and 4 need to perform a series of X-ray images of the spinopelvic complex with an assessment of all the necessary parameters (GLL, PI, PT, SS) and their dynamics in various functional positions (lying on the back, sitting, standing), as well as to assess the potential risk of postoperative dislocation of the head of the femoral component, which is known to occur most often when moving from one position to another.

Thus, due to the lack of consensus regarding the optimal position of the acetabular component of the endoprosthesis in patients with different types of sagittal balance and the degree of spine-and-pelvis mobility, a better understanding of the spinopelvic relationships and their changes that occur with postural change, if a patient has hip-spine syndrome, after hip joint arthroplasty, as well as their effect on the spatial orientation of the acetabulum and, as a result, on the frequency of postoperative dislocations.

It is necessary to combine the knowledge of surgeons of various specialties – specialists in joint arthroplasty and vertebrologists to achieve the best results in the treatment of patients in need of total hip arthroplasty.

Conclusion

Patients with type 3 sagittal balance according to Roussouly have a significantly lower risk of postoperative dislocation of the prosthetic femoral head after total hip arthroplasty compared with types 1, 2 and 4 patients: in patients with types 1 and 2 sagittal balance, dislocation occurs 1.84 times more often, and in patients with type 4 – 1.66 times more often.

Identification of sagittal balance variants in patients, potentially associated with a higher risk of dislocation, requires a more complete preoperative examination and operational planning of total hip arthroplasty.

Table 1

The results of statistical analysis of the comparison of two groups

Indicator	Group I (n = 60)		Group 2 (n = 53)		Comparison results	
	n (%)	Me [Q1; Q3] M ± m	n (%)	Me [Q1; Q3] M ± m	difference [95 % CI]	p-value
PI	60 (100)	53 [43.75; 62.00] 52.95 ± 13.57	53 (100)	51 [41.00; 64.00] 53.70 ± 14.18	0 [-5; 6]	0.874
SS in the standing position	60 (100)	40 [36.00; 47.00] 41.43 ± 10.18	53 (100)	41 [30.00; 49.00] 39.87 ± 12.14	-1 [-6; 4]	0.758
GLL	60 (100)	53 [45.50; 61.00] 52.23 ± 13.56	53 (100)	55 [47.00; 62.00] 54.09 ± 14.12	2 [-3; 7]	0.432
GLL calculated	60 (100)	62.5 [53.75; 71.00] 62.37 ± 13.40	53 (100)	60 [50.00; 73.00] 62.51 ± 13.82	0 [-5; 5]	0.970
SS in the sitting position	0 (0)	NA	5 (9)	42 [21.00; 59.00] 38.20 ± 22.20	–	–
Angle Inclination	60 (100)	43 [39.00; 48.00] 43.67 ± 6.76	49 (92)	50 [41.00; 54.00] 47.88 ± 11.33	4 [1; 8]	0.024
Anterior Acetabulum (Lewinnek method)	60 (100)	20 [10.00; 28.50] 21.05 ± 12.58	50 (94)	10 [5.00; 19.00] 13.26 ± 10.78	-8 [-13; -4]	<0.001
Anterior Acetabulum (Pradhan method)	60 (100)	20 [9.00; 28.25] 20.42 ± 12.43	50 (94)	12 [6.00; 17.00] 13.42 ± 10.71	-7 [-12; -3]	0.002
Anterior Acetabulum (Liaw method)	60 (100)	18 [11.75; 26.25] 19.48 ± 11.77	50 (94)	12 [6.00; 20.75] 14.56 ± 10.99	-5 [-9; -1]	0.015
Type of posture according to Roussouly	60 (100)	1. 2 – 14 (23.3 %) 3 – 29 (48.3 %) 4 – 17 (28.3 %)	53 (100)	1. 2 – 19 (35.8 %) 3 – 13 (24.5 %) 4 – 21 (39.6 %)	–	Common comparison: 0.030; category: p; correction p: 1, 2: 0.154; 0.231 3: 0.011; 0.034 4: 0.235; 0.235

Table 2

Models of logistic regression of dislocations

Predictor	OR [95% CI]	p	OR [95% CI]	p
	Single-factor model		Multi-factor model	
Anterior Acetabulum (Lewinnek method)	0.94 [0.91; 0.98]	0.002	0.95 [0.91; 0.98]	0.004
Anterior Acetabulum (Pradhan method)	0.95 [0.91; 0.98]	0.004	–	–
Type of posture according to Roussouly (1 – 3; 0 – others)	0.35 [0.15; 0.76]	0.010	0.29 [0.11; 0.70]	0.007
Angle Inclination	1.05 [1.01; 1.10]	0.022	1.07 [1.02; 1.13]	0.010
Anterior Acetabulum (Liaw method)	0.96 [0.93; 0.99]	0.030	–	–
Type of posture according to Roussouly (1 – 1,2; 0 – others)	1.84 [0.81; 4.23]	0.147	–	–
Type of posture according to Roussouly (1 – 4; 0 – others)	1.66 [0.76; 3.68]	0.207	–	–
SS	0.99 [0.95; 1.02]	0.454	–	–
GLL	1.01 [0.98; 1.04]	0.473	–	–
PI	1.00 [0.98; 1.03]	0.773	–	–
GLL calculated	1.00 [0.97; 1.03]	0.955	–	–

OR – odds ratio; CI – confidence interval

Limitations of the study reliability: the retrospective nature and the impossibility of preoperative (before arthroplasty) analysis of the features of the sagittal balance in the study group.

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