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Dislocations after Hip Arthroplasty (Review)

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Abstract

One of hip arthroplasty complications is dislocation of the endoprosthesis head. In the vast majority of cases, the cause of dislocation is multifactorial. That is why only a thorough analysis of the patient's peculiarities, surgery and rehabilitation will help to avoid the relapse. This review analyzed the risk factors of dislocation and treatment tactics. Risk factors associated with the patient: old age, male gender, obesity, concomitant diseases, low level of preoperative physical activity, low compliance and a some others. The problem of the biomechanical ratio in the segment "spine – pelvis – lower limb" deserves special attention. Besides, there are risk factors associated with the surgeon: access option; type, fixation and position of endoprosthesis components, experience and surgical technique of a orthopedic surgeon. The strategy of dislocations rate reduction is based on a detailed study of dislocation causes and their elimination, and adequate surgery planning. The treatment of a patient with dislocation should take into account its multifactorial etiology.

Keywords: hip arthroplasty, dislocations, surgical tactics, risk factors, arthroplasty complications.

The problem of dislocations after total hip arthroplasty (THA) exists exactly as long as the THA itself. Assuming that the era of modern arthroplasty began in 1950–1960s from the works of G.K. McKee and J. Charnley, the dislocations, their causes and tactics of actions were discussed in the very first reports on the THA experience [1, 2].

M.G. Lazansky, analyzing the cases of dislocations after THA in the 1960s, singled out among their causes only risk factors related to the surgeon, determined by the operation technique. He recommended that it was important to:

1) perform refixation of the greater trochanter more laterally and distally;

2) choose the adequate length of the endoprosthesis neck in order to restore the tension of the capsule and muscles;

3) placement the acetabular component correctly (the maximum possible medialization of the cup with an inclination angle of 45° and several degrees of anteversion);

4) preserve the acetabular anterior and posterior "labra";

5) limit the early range of motion after the surgery until a strong fibrous capsule was obtained [3].

The understanding of dislocations nature has considerably changed since then, however, both implants and the surgical technique have evolved. More than half of dislocations cases occur in the first 3 months [4, 5, 6] or in the first 3 weeks after the surgery [7]. The early dislocations leads to an increase in financial costs by 342% compared to uncomplicated THA in Italy [8]. The recurrent dislocations increase costs by another 300% (compared to a single dislocations) in the UK [9]. In our country, 8% of early revisions are performed for dislocations [10].

The latest meta-analysis by S.K. Kunutsor et al., included 125 studies with a total of 4,634,000 THA performed from 1969 to 2017, showed that the rate of dislocations after THA was 2.10% (95% CI 1.83–2.38; min 0.12%; max 16.13%) [11]. The prediction interval was from 0.25 to 5.41%. This means that the true dislocations rate in each new study will be within this range with a 95% probability.

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The fundamental difference between "registry" and "cases series" studies of dislocations is that registry studies show only cases of revisions, including those related to dislocations, and, accordingly, do not take into account cases of successful conservative tactics. The case series studies record cases of dislocations and may record cases of revisions. Thus, among the case series (without registry studies, the rate of dislocations was slightly higher and amounted to 2.28% (95% CI 1.93–2.66) with a mean follow-up of 5.8 years. The average rate of revisions for dislocations was 0.88% (95% CI 0.66–1.12) with a mean follow-up of 6.5 years [11].

The rate of dislocations gradually decreases with the development of THA: 3.5% in the 1970s; 3.7% – in the 1980s; 2.1% – in the 1990s; 2.0% – in the 2000s, and 1.7% – in the 2010s (p = 0.016) [11].

This review focuses on the risk factors of dislocations and treatment tactics. The etiology of dislocations is multifactorial and includes risk factors associated with:

1) the patient;
2) the surgeon;
3) the implant.

Many of the risk factors interact with each other. The strategy to reduce the risk of dislocations is based on a thorough analysis of the patient's characteristics, preoperative planning, an understanding of biomechanics and anatomy, and adequate surgical technique.

Duration of the first dislocation

It should be noted that the later a dislocations occurs after the surgery, the higher the likelihood of a second and subsequent dislocations. S.A. Brennan et al. showed that in the patients with multiple dislocations, the median duration of the first dislocations was 13 weeks after the surgery, and in the patients with a one-time dislocations – 3 weeks. [12]. *Early* (up to 3 weeks) first dislocations may indicate non-compliance and/or the presence of reasons associated with the surgeon (inadequate restoration of soft tissue tension, approach deficiencies, gross malposition of the implant). *Late* (within months after the surgery) first dislocations are due to less pronounced miscalculations in the positioning of the implant and inadequate choice of components. It is also possible to distinguish the *distant* first dislocations that occur years after the surgery. They can be caused by wear of the liner and a corresponding change in the biomechanical balance [13]. S.A. Brennan et al. found that with early first dislocations, the likelihood of recurrences was less if the surgery was performed through the anterolateral approach, compared to the posterior or transtrohanteric approach [12].

Patient-related risk factors

Age

Dislocations are more common in older patients. The patients aged 70 years and older in comparison with the patients aged less than 70 years have the *relative risk* (RR) 1.27 (95% CI 1.02–1.57) [11]. The age over 75 years gives an even greater increase, *odds ratio* (OR) 1.96 (95% CI 1.18–3.38) [14]. The increase of age for each year leads to an increase in RR by 1% (RR 1.01; 95% CI 1.0–1.03) [11].

Gender

Dislocations in men are slightly less common than in women: RR 0.97 (95% CI 0.88–1.08 [11].

Body mass index

The impact of *body mass index (*BMI) on the risk of dislocations is not so unambiguous. The studies on this issue are very heterogeneous and often do not allow establishing any significant differences in the meta-analysis. Perhaps, we can confidently talk about the negative impact of only morbid obesity with a BMI ≥50 compared with a BMI <50 (RR 1.4; 95% CI 1.31–1.50). In other cases, the RR was either close to one (1.05 for BMI ≥50 vs <50), or the differences were statistically insignificant (BMI ≥35 vs <35; ≥25 vs <25; underweight vs obesity) [11].

Comorbidity

The presence of comorbidities generally increases the risk of dislocations. ASA risk of 3 to 4 points vs 1 to 2 points gives an RR of 3.2 (95% CI 1.54-6.63). ASA 2 points vs 1 point – RR 1.2 (95% CI 1.05-1.39). The remaining comparisons (3 vs 1 and 4 vs 1 point) did not show significant differences due to the heterogeneity and the size of the studies. The Charlson comorbidity index of 1 point or higher was a significant risk factors compared with 0 points, RR 1.6 (95% CI 1.3–1.96) [11]. It should be understood that an increase in scores on the ASA or on the Charlson index may be due to the presence of diseases that both affect and do not affect the risk of dislocations. That is why we will review the specific nosologies and their impact on dislocations risk.

Specific comorbidities

Among the comorbidities that can increase the risk of dislocations, neuromuscular and cognitive disorders are traditionally feared. A meta-analysis showed that the presence of a neurological disease in the patient increases the risk of dislocations by 2.5 times (RR 2.54; 95% CI 1.86–3.48) [11]. Recall that the meta-analysis included surgeries performed since 1969. Obviously, since then, both endoprosthetics itself, implants, and the treatment of concomitant diseases have changed significantly. A separate analysis of relatively recent work on this topic reveals a less dramatic picture.

A study of the US Nationwide Readmissions Database (2,842 dislocations occurring on average 40 days after the surgery) showed that dislocations were more common in the patients with Parkinson's disease (OR 1.63; 95% CI 1.05–2.51; p = 0.03), with dementia (OR 1.96; 95% CI 1.13–3.39; p = 0.02), with depression (OR 1.28; 95% CI 1.13–1.43; p <0.0001) [15]. However, other studies failed to establish such a connection. R.M. Meek et al., based on data from the Scottish Arthroplasty, did not find significant differences in the rate of dislocations in the patients with and without Parkinson's disease, and even made the appropriate recommendation to surgeons not to fear Parkinson's disease when making a decision about THA [16].

Moreover, in a recent cohort case-control study, M.T. Houdek et al. found no difference in the rate of complications, including dislocations, after THA for osteoarthritis in the patients with cerebral palsy (39 patients) and without it [17]. On the other hand, this study included a small number of patients.

The analysis of the National Joint Registry for England, Wales, Northern Ireland showed that among the patients with cerebral palsy (389 cases), dislocations occurred in 4 (1.02%). The differences with the control group of the patients without paralysis (425 813 patients) are insignificant [18]. However, it should be understood that the registry study counts cases of revisions due to instability, not cases of dislocations. Anyway, the existing data suggest that cerebral palsy is not a risk factors. It is possible that these data will be adjusted as new studies become available.

The risk factors for dislocations include age-related cognitive disorders, accompanied by mental illness and alcoholism [16, 19]. The retrospective analyzes of the Danish Hip Arthroplasty Registry showed that the patients receiving therapy for mental illness had a higher risk of dislocations (OR 2.37; 95% CI 1.29–4.36) [20]. In the meta-analysis, the presence of mental illness (without specification of pharmacotherapy) gave an RR of 1.35 (95% CI 1.18–1.54) [11]. Alcohol abuse (more than 2 liters of beer or more than 180 ml of strong alcoholic beverages per day) is also a significant risk factors for dislocations [21]. In a meta-analysis compared the rate of dislocations in alcohol abusers with non-abusers, the RR was 1.17 (95% CI 0.84–1.64) [11]. Risk factors in some rare studies include chronic obstructive pulmonary disease (OR 1.2; 95% CI 1.07–1.33; p = 0.001) [15]. The presence of diabetes, neurodegenerative diseases, peripheral vascular diseases, renal failure is not a reliable risk factors for dislocations [11].

Training, assistance and compliance

The risk of dislocations increases both inadequate training of the patients in postoperative rules for limiting physical activity [22] and inadequate patient's compliance [23]. In a prospective cohort study comparing the patients with and without preoperative training, the latter was found to reduce the absolute risk of dislocations by 1.3% [22]. Dislocations occur more frequently when a patient was discharged home from the surgery than when transferred to a rehabilitation center with nursing care (RR 1.46; 95% CI 1.29–1.65). Rehabilitation assistance with home visits also reduces the rate of dislocations, but not so dramatically, RR "home" vs "home help" is 1.06 (0.94–1.19) [11].

Physical activity level

The level of physical activity of the patient before the surgery, as an integral indicator of the patient's morbidity, is also a risk factors for dislocations. C.I. Esposito et al. found that in the patients with dislocations, the average preoperative status on the Lower Extremity Activity Scale was 9 ± 3 points. It was significantly lower than in the patients without dislocations (10 ± 3 points, p = 0.001) [24].

Indications for arthroplasty

Studies on the effect of pre-arthroplasty fractures of the femoral neck and head on the risk of dislocations had mixed results. In a 2003 study, no relationship was found between fracture and the risk of dislocations [25], and in a 2006 registry study, fractures of the femoral neck prior to THA increased the risk of dislocations compared with elective surgery (OR 1.79) [16]. The meta-analysis, due to multidirectional results, did not find any statistical differences in the rate of dislocations (RR 1.02; 95% CI 0.61–1.72) [11]. THA for osteonecrosis of the femoral head, according to most authors, leads to an increase in the risk of dislocations, but according to other data, it does not [26]. For example, E.B. Gausden et al. determined OR 1.67 (95% CI 1.45–1.93; p <0.0001) [15]. In a meta-analysis by S.K. Kunutsor et al., there is an unclear point: as a risk factors, avascular necrosis is analyzed separately (RR 1.71; 95% CI 1.33–2.18) and osteonecrosis separately (RR 1.48; 95% CI 1.11– 1.97) [11]. For some unknown reason, the authors considered that avascular necrosis and osteonecrosis are different diseases. Although in fact, they are one and the same disease of the femoral head. Most likely, there is another "grimace of evidence-based medicine", when medical statisticians separately analyze states and draw conclusions, but in fact they analyze the same thing.

THA for rheumatoid arthritis is a significant risk factor (RR 1.94; 95% CI 1.65–2.27) [11].

Revision THA is associated with a risk of dislocations up to 28% [23], and the RR of dislocations after revision is 3.43 (95% CI 1.45–8.13) [11]. Of course, such a high rate is due to significant soft tissue defects, nonunion fractures, or bone defects in the trochanteric region [27]. There are a lot of studies demonstrated an increased risk of dislocations after revision THA, but we prefer not to dwell on them in more detail, because the volume of revision and, accordingly, soft tissue and bone defects can vary significantly and depends on the specific clinical case, which explains the wide 95% confidence interval (1.45–8.13) of the RR in the meta-analysis [11].

Cup size

Cup size is another risk factors. On the one hand, this is a patient-related factor, since the cup size is determined by anatomy. On the other hand, within certain limits, the surgeon also influences the choice of size, so it can be considered a little modifiable, but nevertheless modifiable factor.

R. Peter et al. found that with a cup diameter less than 56 mm, the rate of dislocations varied from 0.6 to 2.4%, depending on the specific diameter, and with a diameter of 56 mm and more, from 4.1 to 5.2% (RR 2.9; 95% CI 1.2–4.9, head diameter 28 mm) [22]. It is likely that in this study, other factors determining cup size were more influential than the distance of the "jumping" itself, i.e. it is possible that cup size is a proxy factor. S.S. Kelley et al. (1998) came to the similar conclusions. The rate of revision for dislocations in the patients with cups ≥ 62 mm was significantly higher (5 of 36.14%) compared with the cups of 60 mm and less (11 of 272, 4%) [28]. Surprisingly, but in a 2019 meta-analysis, S.K. Kunutsor et al. gave completely different data [11]. Supplementary material to the meta-analysis states that the effect of the cup diameter was evaluated in three studies. In one study, diameters ≥56 vs <56 mm were compared [22], in another study – ≥62 vs <60 mm [28], and in the 3rd study – ≥54 vs <54 mm (we could not identify this work). In the meta-analysis itself, S. Kunutsor et al. did not give links to any paper. In particular, S.K. Kunutsor et al. claimed that a cup diameter ≥56 mm reduced the risk of dislocations (RR 0.42; 95% CI 0.21-0.86), while a diameter ≥ 62 mm, on the contrary, increases (RR 3.43; 95% CI 1.27-9.29) [11]. Referring to the full texts of the R. Peter et al. [22] and S.S. Kelley et al. [28], it becomes clear that this is not the case: a large diameter increases the risk of dislocations in both works. It is difficult to assume that S.K. Kunutsor et al. made a technical mistake by rearranging the diameters (≥56 vs <56 mm instead of <56 vs ≥56 mm, then they would have received inverse relative risks, i.e. 1/RR). If this technical error had occurred, the results of the two studies would still have the same focus (reduce or increase the risk), but S.K. Kunutsor et al. received the mixed results. It will be very annoying if we have another “grimace of evidence-based medicine”, but in this case it was caused not by the disadvantages of evidence-based medicine itself, but by the authors' mistake. In connection with this and other completely incomprehensible moments, we wrote a letter to the *The Lancet Rheumatology* editor, which published this meta-analysis [11] and hope to get answers to our questions.

Spinopelvic balance

Simultaneous spine and hip lesion is quite common [29, 30]. The biomechanical pelvic disorders arising against this background in the context of THA deserve special attention [31, 32]. The patients with spinal arthrodesis, degenerative diseases of the lumbar spine, various deformities have a significantly higher risk of dislocations after THA. D.C. Perfetti et al. reported an OR of 7.19 [33]. In other works, the OR value is not so dramatic, but also very large. For example, E.B. Gausden reported that spinal arthrodesis was the most significant independent risk factors for dislocations within 40 days after THA (OR 2.45; 95% CI 1.97–3.04; p <0.0001) compared with all others [15].

A.J. Buckland et al. for the patients with arthrodesis at levels 1 to 2 had an OR of 1.93 (95% CI 1.42–2.32; p <0.001), and arthrodesis at levels 3–7 gave an OR of 2.77 (95% CI 2.04-4.80; p <0.001) [34]. D.C. Sing et al. reported a similar correlation between the risk of dislocations and the number of vertebral arthrodesis levels. The rate of dislocations: in their study with arthrodesis at levels 1 to 2 was 4.26%, and at 3 or higher – 7.51% (in the control group – 2.36%; OR 1.8 and 3.2, respectively) [35]. Moreover, in the above-mentioned work by D.C. Perfetti et al. a higher risk of revision in the patients with lumbar arthrodesis was found, OR 4.64 [33]. A high risk of revision for instability in the patients with impaired sagittal spine-pelvic balance was also noted in the study of E.M. DelSole et al., from 5.8 to 8.0% [36].

Anteversion and inclination of the cup

A meta-analysis showed that an abduction inclination of the cup over 50° increased the risk by almost 3 times (RR 2.96; 95% CI 1.44–6.10), an inclination of more than 55% – by almost 8 times (RR 7.7; 95% CI 2.30–26.00) [11]. Further in the meta-analysis, we found another inaccuracy. The authors wrote that positioning the cup in the range of 35 to 50° inclination and 5 to 25° anteversion led to an increased risk of dislocations (RR 3.42; 95% CI 1.78-6.56) [11]. This is certainly not the case. Referring to the original study of R. Biedermann et al. [7], we found that, the authors considered the "safe range" to be 30 to 50° inclination and 5 to 25° anteversion, and not 35 to50° inclination, as noted in meta-analysis [11]. It would seem that 5° errors are not so much, but the inaccuracies do not end there, and if "... the clock has struck thirteen times, then not only the thirteenth beat, but all the previous, causes distrust." In the outlined "safe range" in the study of R. Biedermann et al., 79% of cases of the control group (without dislocations) took place, but the percentage of cases from the group of "dislocations" who were in the "safe zone" was much smaller and amounted to 60% (by the χ^2; p <0.01) [7]. A similar “reverse” of the RR in the meta-analysis is observed for other cup anteversion in the ranges of 10 to 30°, 10 to 20°, and 0 to 20° [11]. On the one hand, this inaccuracy is just an inaccuracy, not a critical error, but it shows another “grimace of evidence-based medicine”: you cannot blindislocationsy trust the results of a meta-analysis without understanding the principles of its construction and, in fact, the clinical problem. In view of this, another meta-analysis by K.G. Seagrave et al. [37], devoted exclusively to the effect of cup orientation on dislocations risk, is more interesting. We will discuss it in a moment [37].

Recent scientific evidence is blurring the line between patient-related and surgeon-related risk factors for dislocations. Most of all, this border is erased, paradoxically, in the issue of the acetabular component orientation.

G.E. Lewinnek et al. paper "Dislocations after total hip arthroplasty", published more than 40 years ago, became a classic, included in all guidelines for THA, and is cited more than 2000 times [38]. The authors wrote: "There are relatively safe cup orientation angles … 40°±10° lateral inclination and 15°± 10° anteversion … proven to be the safest." A critical analysis of the above mentioned study in accordance with modern views, revealed serious limitations [39]. The authors reported 300 THA performed by 5 surgeons, but 178 (59%) of them were not included in the analysis. However, they estimated a dislocations rate of 1.5% when "adhering to safe inclination and anteversion ranges" based on a total of 300 THA, not 122 as would have been expected. Three of the nine dislocations occurred in the "safe zone". In addition, the X-rays were "standardized" according to an imperfect technique, which found little subsequent use elsewhere. One in five surgeons performed 190 THA, and among them there was only 1 (0.5%) dislocations, although the rate of placing cups outside the "safe zone" was the same as revealed other 4 surgeons with much less activity. That surgeon noted that "success depended on many factors, such as adequate soft tissue tension to achieve clinical stability on the operating table and avoid adduction for 6 weeks after the surgery". Thus, even in the original article G.E. Lewinnek and co-authors themselves spoke about the multifactorial nature of the dislocations, but concluded about the "safe zone" of inclination and anteversion.

At the All-Russian Congress of Orthopedic and Trauma Surgeons (Moscow, 2014), in our report we mentioned the study of C.I. Esposito [24]. Its journal publication was made in 2015, and an advance electronic publication was available in July 2014. We referred to this work in the context that cup inclination and anteversion did not affect the risk of dislocation. And we perfectly remember the surprise, if not the complete disagreement, of the audience with the voiced "heretical" data.

The first evidence of the absence of a relationship between the risk of dislocations and the cup orientation was published back in 2011 [40], and in 2016 and 2017 three more qualitative works appeared [36, 41, 42], which strengthen C.I. Esposito data [24]. These studies indicated both the fact that surgeons often fail to obtain the recommended cup orientation angles in the Lewinnek zone [38], and the absence of predictive value of angles due to the risk of mechanical complications, including dislocations. In other words, the majority of dislocations occurred precisely when the recommendations for cup orientation in the Lewinnek zone were fully followed [41]. However, the authors did not explain the reasons for this low or absent predictive value [24, 36, 40, 41, 42].

When a person is standing, the pelvis is inclined anteriorly, the lumbar spine has lordosis, and the acetabulum relatively covers the femoral head. When a person is sitting, the lumbar lordosis decreases, the pelvis inclined posteriorly by an average of 20°, and the acetabulum opens anteriorly [43]. With a normal range of motion at the level of the spine, the ilio-sacral level, the posterior inclination of the pelvis in a sitting position reduces the true angle of femoral flexion [44]. If there is a deficit in the movement at the level of the spine, at the ilio-sacral level, then hypermobility occurs at other levels. In conditions of degenerative problems with the lumbar spine or after spinal arthrodesis, this leads to compensation due to an increase in the range of motion of the thigh, the risk of impingement, and, accordingly, dislocations after THA [36, 45]. One recent study found that a loss of one degree of pelvic inclination resulted in an increase in thigh amplitude by 0.9° [46]. This functional reality limits the "safe zone", which is essentially only relevant for a static vertical position. The posterior pelvic inclination in the seated position "opens" the acetabulum due to impingement with a flexing thigh [43]. The contribution of the thigh to the posterior inclination of the pelvis in the sitting position due to impingement has been confirmed in laboratory studies by K.H. Widmer and B. Zurfluh [47], J.M. Elkins et al. [48]. From this point of view, at the present stage, perhaps, we can say that only simultaneous anteversion of the acetabulum and anteversion of the thigh (more precisely, antetorsion) lead to dislocations after THA, and not the position of the cup itself. Moreover, C.I. Esposito et al. showed that thigh movement is even more significant than cup position in the etiology of impingement and the risk of dislocations [24]. Other authors came to the similar conclusions [43, 49, 50, 51].

The spatial position of the hip includes the sagittal inclination of the pelvis with a change in the acetabular angles and the movement of the thigh proper during flexion and extension. T. Tezuka et al. proposed to evaluate the combination of changes in these angles (acetabulum and femur), visible on the lateral lumbar-pelvic X-ray, with a special "combined sagittal index" [49]. In this paper and in the article by H. Ike et al., a new term "functional safe zone" [44] was coined, as opposed to the static "safe zone" according to Lewinnek, visible on the antero-posterior plane.

Twenty years ago A.M. DiGioia et al. received the Hip Society Award for the theory of the sagittal axis importance in the acetabular component functioning [52]. The theory was developed, and other authors began to study sagittal changes in the chain "spine – pelvis – hip" and their effect on the cup orientation in changing body position [24, 50, 53]. In some studies, the authors talked about the risk of dislocations after THA with a reduced amplitude of functional pelvic inclination against the background of ankylosing problems in the lumbar spine and/or vertebral arthrodesis [34].

Some authors reported an extremely high rate of dislocations (up to 8%) after THA in the patients with concomitant pathology of the spine, despite the positioning of the acetabular components in the "safe zone" [36, 54]. Surgeons are increasingly confident that the intraoperative orientation of the cup, even clearly in the "safe zone" according to Lewinnek, may be insufficient to prevent dislocations in the presence of functional orientation change. All these modern studies change the simplified concept that the absence of dislocations depends on the fulfillment of some specific conditions for the acetabular component orientation, assessed by the antero-posterior X-ray. The 40-year-old Lewinnek criteria [38] are not really criteria for the absence of dislocations. The paradigm is changing: the surgeon must make an effort for an individual orientation of the components, functionally demanded by a particular patient. In the hospitals where THA is performed, the pre- and postoperative sagittal X-rays are increasingly performed in a sitting and standing position, especially in the patients with a high risk of dislocations. In this context, this category can include the patients with both hypermobility and reduced range of motion for various lumbar spine pathologies [55]. Moreover, in recent studies, in addition to X-rays in a sitting and standing position, it is recommended carrying out the functional X-rays in a position where one of the patient's legs stands on a step of a ladder, simulating an upward climb [45].

Perhaps the "functionally safe zone" approach will justify itself and will indeed lead to a decrease in the rate of dislocations and the revisions caused by them, but there are practically no such works so far. In one of the works of 2018, N. Heckmann et al. [46] studied the effect of the "functionally safe zone", assessed by the already mentioned new "combined sagittal index", on the risk of dislocations [49]. In 2014, Y. Nakashima and co-authors proposed a combined increase in the total cup and stem anteversion to 50 ± 10° (230 cases), compared with the traditional anteversion group (20° in total). The postoperative CT control of the total anteversion was studied in 111 cases. As a result, they received a significant decrease in the rate of dislocations (0.4% and 2.5% in the groups, respectively, OR 5.8 after removing the risk factors "diagnosis" and "head size") [56]. Y. Nakashima et al. did not use the combined sagittal index and the "functionally safe zone" paradigm, which were proposed later, but their idea was close. Such a large total anteversion, although reduces the risk of dislocations, needs more careful study in the context of mechanical wear and other complications. Its use in all patients without pelvic inclination deficiency, in our opinion, is premature.

Changing the paradigm to a "functionally safe zone" does not require a change in the surgical technique, but only means the surgeon's greater attention to the functional movement of the pelvis and the thigh is important to determine the cup inclinations and cup and stem anteversion required in an individual case [57]. For example, due to some illness or after spinal surgery, there may be a deficit in the lumbar spine movement, and the amplitude of the pelvic inclination when standing up or sitting down is also significantly reduced. Such a spinal pelvic imbalance requires at least a greater anteversion and, possibly, inclination, the degree of which is determined intraoperatively [44, 51]. If the required stability cannot be achieved by intraoperative change in the orientation of the cup, then intraoperatively, other stabilization methods should be used, including dual mobility systems.

On the other hand, one should abandon the encountered cases of criticism, when on postoperative X-rays in the antero-posterior plane, deviations from the classical ranges according to G.E. Lewinnek (inclination 40±10° and anteversion 15±10°) are visible. The change in orientation could and should have been made to obtain functional stability, in particular in the patients with hip-spine syndrome. In this regard, the recent work of 2019 by professors L.D. Dorr and J.J. Callaghan deserves attention. The authors called their paper "Death of the Lewinnek «Safe Zone» [55].

In the 2017 meta-analysis mentioned above, K.G. Seagrave et al., combined the results of 28 studies examining the effect of cup position on the risk of dislocations, concluded that "… when comparing the mean angles of anteversion and inclination in the patients with and without dislocation, most studies did not show significant differences… It is difficult to define the boundaries of the safe ranges for cup orientation in THA. The target cup orientation is different for each patient and depends on many factors. Positioning the cup within the recommended ranges does not eliminate the risk of dislocations, but can reduce it"[37].

Risk Factors Associated with a Surgeon

Surgical approach

The posterior approach is traditionally popular, but in the last decade, the anterior approaches have been used more and more, since they, probably, make it possible to reduce the duration of inpatient treatment, the intensity of pain, and more likely to restore joint function [58].

D. Sheth et al. analyzed 22,237 cases of arthroplasty (mean follow-up of 3 years) found that when compared with the posterior approach, the antero-lateral approach reduces the risk of dislocations by more than 3 times (OR 0.29; 95% CI 0.13–0.63; p = 0.002), and the direct anterior approach more than doubled (OR 0.44; 95% CI 0.22–0.87; p = 0.017). No differences in the rate of dislocations were found between the anterior and antero-lateral approaches [59].

In our clinical practice, we obtained the similar data. In two departments of traumatology, orthopedics and joint pathology clinic at the Sechenov First Moscow State Medical University from 2012 to 2014, 1623 primary THA were performed. Medium-term results on average in 1.5±0.7 years were followed in 100% of the patients, long-term (in 5.9±1.1 years) – in 62% (1006 patients, remote questionnaire). In one department, the antero-lateral approach was used (839 patients, 3 surgeons), in the other, the posterior approach (784 patients, 3 surgeons). Medium-term dislocations occurred in 9 (1.1%) patients with antero-lateral approach and in 33 patients with the posterior (4.2%; OR 3.9; p = 0.0001). Long-term results were added one case to each group: the rate 1.2% and 4.3%, respectively (OR 3.6; p = 0.0001).

On the other hand, in the work of J.D. Maratt et al., the dislocations rate after direct anterior approach was the same as after the posterior (0.84% and 0.79%, respectively) [60].

The etiology of dislocations is multifactorial, and the same rate of dislocations in the anterior and posterior approaches in the study by J.D. Maratt et al. meant that the surgeons were able to compensate for such a risk factors as the posterior approach by influencing other risk factors (positioning, for example) [61]. This signified that endoprosthetics with various approaches should differ not only in the approach. In the context of the multifactorial etiology of dislocations, it can also be remembered that in revision THA, the rate of dislocations does not depend on approach [62].

However, in most studies, surgeons fail to minimize the negative impact of the posterior approach by correcting other risk factors. The meta-analysis shows that the risk of dislocations with the posterior approach is greater than with antero-lateral (15 studies; RR 2.00; 95% CI 1.39–2.87), direct anterior (13 studies; RR 1.76; 95% CI 1 , 2–2.5) and lateral (9 studies; RR 1.61; 95% CI 1.17–2.21). The differences in the rate of dislocations in the comparisons: the posterior vs trans-trochanteric approach (5 studies), anterior vs postero-lateral (3 studies), minimally invasive posterior vs traditional posterior, minimally invasive anterior or antero-lateral vs lateral, lateral vs antero-posterior, mini-two-approach technique with mini-posterior (one study for each approach) turned out to be insignificant [11].

A trochanteric osteotomy with the lateral approach reduces the risk of dislocations compared with the lateral approach without osteotomy (one study; RR 0.2; 95% CI 0.08–0.49) [11].

The advantages of the anterior approach, including the reduced risk of dislocations, often urge the surgeons to retrain and change their preferences, but many refuse to change, as they rightly fear the complication growth during the learning curve. X. Kong et al. published their experience of the learning curve from posterior to anterior approach. After the first 50 surgeries, they received 2 dislocations. There were no dislocations among the subsequent surgeries, but they note that after the first 50 surgeries they began to use fluoroscopic control of implant positioning [63].

Impingement

The classical theory of impingement as a key mechanism of dislocations was formulated by H.C. Amstutz et al. in 1975 [64]. Analysis of implants removed in revision due to dislocations showed that 80% of cups and 94% of liners had signs of impingement, while in revision for other reasons this proportion was 51% and 56% respectively [65]. H. Miki et al. argued that impingement was the main risk factors and trigger mechanism for dislocations, and impingement itself was primarily determined by implant malposition [65], which was especially important from the point of view of the "functionally safe zone" already described in the patients with spinal pathology.

Impingement can be reduced or eliminated by increasing the ratio of the diameters of the head and neck, which will lead to an increase in the amplitude before the moment of impact (Fig. 1) [66].

With the limited influence of the surgeon on the diameter of the neck, this ratio changes mainly by increasing the diameter of the head.

The implant head

Historically, the change of diameters to the larger was not entirely smooth. The heads with a diameter of 32 mm led to a greater volumetric wear of polyethylene and, accordingly, to osteolysis around the endoprosthesis components. The advent of cross-linked polyethylene and ceramics has solved this problem.

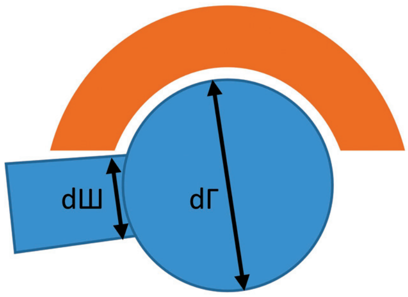

Fig. 1. Ratio of the head and neck diameters and the rate of impingement (by A.P. Sereda).

In one of the first works on this topic, G.M. Alberton et al. showed that 28 mm and 32 mm heads reduced the risk of dislocations compared to the now-gone 22 mm heads [27]. In the subsequent works, the similar data were obtained: RR 2.4 when comparing 22.2 mm with larger diameters [67]; RR 2.0 when comparing 22.2 mm to 28 mm [68]; RR 1.2 when comparing 22.2 mm to 32 mm [69]. A decrease in the risk of dislocations with large-diameter heads occurs due to the increased "jumping distance" and greater amplitude without impingement (increased ratio of the head to neck diameters) [25]. Of course, the increase in the head diameter was accompanied by a decrease in the liner thickness [70].

A further increase in the head diameter (from 28 mm to 32 mm) led to a less unambiguous decrease in the rate of dislocations. For example, N.P. Hailer et al. compared the 28 mm diameter with 32 mm. They found that the RR of dislocations amounted to 1.3, and to 2.0 in comparison of 22.2 mm vs 28 mm [69]. T.H. Magee et al. argued that the risk of dislocations did not depend on the head diameter (28 mm and more) [71]. Although it should be noted that T.H. Magee et al. studied only 17 cases of dislocations in total for all head diameters. An even larger, 36 mm diameter of the head, allowed the further reduction of the dislocations risk: by 3.6% (95% CI 0.9–6.8%) during the 1st year after the surgery compared with 28 mm [68]. This, of course, was much less than the drastic reduction in dislocations in comparison of 22 mm vs 28 mm and 32 mm, or 28 mm vs 32 mm. The advantage of larger diameter heads was found in any approach [72].

In the meta-analysis by S.K. Kunutsor et al. [11] on the relationship between the risk of dislocations and the head diameter comprised 50 works, including comparing some exotic diameters: 30, 26 and 40 mm. Significant differences were found only in comparison of 28 mm vs 32 mm (12 works; RR 1.67; 95% CI 1.28–2.18), 22 mm vs 32 mm (6 works; RR 1.88; 95% CI 1.51–2.33), 28 mm vs 36 mm (3 works; RR 2.2; 95% CI 1.3–3.8), 32 mm vs 36 mm (2 works; RR 1.56; 95 % CI 1.26–1.92), 26 mm vs 30 mm, and 28 mm vs 30 mm (two works). Comparison of 22 mm with 28 mm resulted in the RR amounted to 3.03 (95% CI 0.66–14.01), but the differences were not significant due to the wide confidence interval of the results of the 3 included works. In other cases (26 mm vs 32 mm; 36 mm vs 40 mm), the differences were also insignificant [11].

Of course, 36 mm heads still have a higher dislocations rate than anatomical heads with bipolar and unipolar THA (4.6% and 0.5%, respectively, at 10-year follow-up) [73]. The bipolar endoprosthesis has the largest ratio of the head-to-neck diameters, respectively, the largest amplitude and distance of "jumping out". However, a bipolar prosthesis has its own indications and limitations.

Liners

Lipped liners can reduce the rate of dislocations by half (RR 0.49; 95% CI 0.36–0.66 based on the results of 4 studies, a total of 16,531 patients) [11].

To minimize the possibility of dislocations, constrained head liners can also be used, especially in the patients at high risk of dislocations. For example, in a retrospective review by J.T. Munro et al. the constrained liners were used in 81 patients at high risk of dislocations, and they occurred in three (3.7%) cases with a mean follow-up of 34 months (minimum of 24 months) [74]. In another work, T. Pace et al. used constrained liners in 137 patients (154 surgeries) with a high risk of dislocations (Zimmer Natural Stem Longevity Constrained Liner, Epsilon cup). The authors reported the dislocations rate of 1.9% in 6 years [75]. It is important to note that T. Pace et al. began using the constrained liners after the dislocations rate in their patients was 9.8%. This, of course, is very high, and, probably, the problem could be solved in another way. Similarly, K. Gill et al. reported 1.8% of dislocations in 45 months after using 55 constrained liners in 54 patients with femoral neck fractures, dementia, neuromuscular disorders, and abductor muscle insufficiency [76]. In other studies, the authors failed to demonstrate the benefit of using the constrained liners. The rate of revisions, including for infections and loosening, was high [72, 77]. The decision to use the constrained liners must be very careful as the revision rate with their use, for other reasons, is very high (16–29%) [76]. The constrained liners must not be used to compensate for inadequately positioned implants.

Soft tissue tension: offset, capsule and muscle

Suturing the capsule after THA allows the additional hip stabilization [78]. Although, after implants are installed, the abductors and the capsule can stretch or shorten, which also affects the risk of dislocations. To reduce the risk of dislocations, it is important to obtain the sufficient tension in the soft tissue complex, including the capsule, short external rotators and gluteal muscles, both after primary and revision THA.

Traditionally, offset is believed to play an important role in stability. In native joints, it ranges from 39 to 43 mm. In these conditions the anatomical restoration is believed to be stable [41]. There is an opinion that the offset needs to be restored not only anatomically, but even with increase. In a recent case-control study (67 dislocations and 245 controls), B. Forde et al. found that an increase in offset by at least 3 mm compared with the contralateral joint reduced the risk of dislocations (*p* = 0.0192), while the risk of dislocations was not influenced by cup inclination, anteversion or differences in limb length. In their opinion, the offset was the most important factor in stability [79]. Some authors in cadaveric studies also came to the conclusion that increased offset, together with a larger head diameter, led to an increase in the safe range of motion and a lower risk of dislocations [80]. However, in other clinical studies [81, 82, 83, 84, 85], these authors failed to find that offset affected the risk of dislocations (Table 1). Nevertheless, the study of B. Forde et al. is the largest in terms of the total number of dislocations studied [79].

The offset can be increased not only by the head, but also by the stem, using lateralized or modular options. It is important to remember that modular stems are at risk of fretting corrosion [86] and many authors do not recommend their routine use [87]. The cost of other complications may be inadequate for the absence of dislocations risk reduction in some studies [84, 85], or the modest reduction in dislocations risk (RR 0.94 only) in others [79].

We support the opinion of J. Dargel et al. that the sufficient soft tissue tension should be achieved not only by increasing the offset, but also by adequate suturing [23]. The tactic of replacing the head with another, with a large offset, during revision for dislocations, as an independent measure, could lead to stability, but we believe that intraoperatively it is difficult to understand whether this will be really enough.

With regard to the tactic of capsule suturing, there are two options: suture only the muscles, assuming that with adequate restoration of the muscle length, the capsule will be scarred with the appropriate suitable length, and do not suture the capsule. Suturing of the capsule is especially important for posterior

Table 1

The influence of offset on dislocation

Authors, year	Group (number of cases)		Results	**Conclusion:** whether the offset affects dislocation?
	A	B		
Cogan A. et al. (2011) [81]	Dislocations after isolated revision of the cup (4)	Without dislocations after isolated cup revision (57)	Femoral offset: (A) 55 ± 17 mm; (B) 47.0 ± 0.9 mm; p = 0.167	Does not affect (but in the group of dislocations it was slightly larger)
Gerhardt D.M. et al. (2014) [85]	Monobloc stems (90)	Modular neck (95)	The difference in abductors moment of force compared to the indicator before surgery: (A) 2.1 ± 0.5 mm; (B) 3.3 ± 0.7 mm; p = 0.048. Dislocations: (A) 4/90; (B) 4/95; p> 0.05	Does not affect
Duwelius P.J. et al. (2014) [84]	Monobloc stems (284)	Modular neck (598)	The difference in the femoral offset compared to the indicator before surgery: (A) 7.5 mm; (B) 6.1 mm; p = 0.047 Dislocations: (A) 5/284; (B) 5/598; p> 0.2	Does not affect
Hartman C.W., Garvin K.L. (2006) [83]	Dislocations after two-stage revision (5)	Without dislocations after two-stage revision (29)	Femoral offset: (A) 36 mm; (B) 46.8 mm; p = 0.07	Does not affect
Robinson M. et al. (2012) [82]	Dislocations (9)	Without dislocations (659)	Femoral offset: (A) 46.9 mm; (B) 50.5 mm; p = 0.19	Does not affect
Forde A. et al. (2018) [79]	Dislocations (67)	Without dislocations (245)	Relative risk of the difference in femoral offset compared with preoperative value ≥3 mm: 0.94 (95% CI 0.89–0.99; p = 0.0192).	Affects

In the study by D. Gerhardt [85], the moment of force of the abductors was measured, not the femoral offset.

and postero-lateral approaches. In one study, capsulorrhaphy reduced the rate of dislocations from 2.8% to 0.6% (1000 patients) [88], and in another – from 4.8 to 0.7% (1515 patients [89]. But the suturing after the posterior approach should be not just soft tissue ("residential"), but reinforced. In the meta-analysis of 7 studies that included 45,594 cases of primary THA, D. Zhang et al. showed a lower rate of dislocations and a higher Harris score in the patients with posterior access and enhanced suturing [90]. The latter included the use of anchoring fixators by Y. Zhang et al. [91] and/or transosseous suture according to EA Spaans et al. [92]. In revision THA, the enhanced suturing also showed efficiency. After revision THA with a posterior approach, the revisions for dislocations was performed in 1.9% [93] and 2.5% [94] of cases in the groups with enhanced suturing and in 10% of cases in the groups with conventional suturing [93, 94]. Recently, S. Aota et al. proposed a new technique of enhanced suturing using the synthetic Leeds-Keio artificial ligament, which, according to their data, made it possible to stabilize the hip in 82% of revisions for complex cases of multiple dislocations [95].

In 1987 S.J. Kaplan et al. proposed to normalize tension by distalizing and, if necessary, anteriorly displacement of the greater trochanter after linear or chevron osteotomy by 1 to 2 cm. They used this technique in 21 patients with chronic dislocations and obtained a stable joint in 17 cases. All four patients with failed stabilization suffered from rheumatoid arthritis, and in 3 cases, according to the authors, the trochanteric advancement was insufficient, and only one patient with sufficient trochanteric advancement remained dislocated. The authors recommended distalizing the greater trochanter during primary THA in the patients at high risk of dislocations [96]. Another interesting direction is the theoretical possibility of arthroscopic restoration of the capsule. At least for the dislocations after arthroscopy (and not after THA), this technique was used (20 patients) [97].

Dual mobility

In the patients with the high risk of dislocations during primary THA, endoprostheses with dual mobility can be used. Historically, there was a concern that dual mobility would result in high volumetric wear on polyethylene, but clinical studies showed good results and a low risk of osteolysis [98]. The rate of dislocations after primary THA using dual mobility was evaluated in 6 studies, which showed a decrease in the rate of dislocations by almost 7 times (RR 0.15; 95% CI 0.08–0.29) [11]. Dual mobility is also an excellent solution for revision THA, which we will discuss in the special section below.

Surgeon experience

All of the above risk factors should be assessed by the surgeon and, if possible, minimized (Table 2). Many aspects of the surgery (approach, choice of implants, their positioning, wound closure technology) depend on the surgeon's knowledge, skills and preferences, and ultimately on experience. It is the experience of the surgeon that also helps to reduce the incidence of dislocations [99, 100]. The incidence of dislocations after THA in the surgeons performing less than 5 operations per year is 50% higher than among the surgeons performing more than 50 operations per year [99, 101].

Table 2

Summary table of patient-related risk factors for dislocation

Risk factor	Odds ratio*	Source
Time. The later the first dislocation occurred, the higher the risk of repeated dislocations	**	[12]
Age >75 years	1.96	[14]
Decreased preoperative physical activity	**	[24]
Morbid obesity, BMI ≥50	1.4	[11]
ASA 3 to 4 points	3.2	[11]
ASA 2 points vs 1 point	1.2	[11]
Charlson Comorbidity Index ≥1	1.6	[11]
Stiffness of the lumbar spine (arthrodesis, ankylosis, etc.)	2.19	[11]
Dementia	1.96	[15]
Depression	1.28	[15]
Cerebral paralysis	Unreliable	[17]
Cerebral paralysis	Unreliable	[18]
Parkinson's disease	1.63	[15]
Parkinson's disease	Unreliable	[16]
COPD	1.2	[15]
Mental illnesses with pharmacotherapy	2.37	[20]
Mental illness (without specifying pharmacotherapy)	1.35	[11]
Alcoholism (>2 liters of beer or >180 ml of spirits per day)	4.95	[21]
Alcoholism (without detailed dose)	1.17	[11]
Compliance	**	[23]
Training of the patients	**	[22]
Discharge home instead of transfer to a rehabilitation center	1.46	[11]
Indication – avascular femoral head necrosis/osteonecrosis ***	1.48–1.71***	[11]
Indication – rheumatoid arthritis	1.94	[11]
Cup diameter (the risk of dislocation is higher with a larger diameter)	2.4	[22]
Revision hip arthroplasty	3.43	[11]

*The ratio of dislocations rate in the patients with a risk factors to the rate of dislocations in the patients without a risk factors. For case-control studies, the indicator is called the odds ratio (OR); for prospective studies, when patients are pre-divided into the groups depending on the presence or absence of a sign, the indicator is called the risk ratio (RR). To simplify our work, we use OR everywhere, with the exception of describing the results of third-party meta-analyzes.

** Calculation is impossible or incorrect (for example, there are no criteria for which the patients can be considered compliant).

*** See explanation in text.

Tactic for dislocation after arthroplasty

Anamnesis

As a rule, the patients themselves report that something "clicked" and "popped out" in them, after which pain appeared [102, 103]. It is important to find out whether this dislocation is the first or repeated, and what kind of movement led to it [23, 104]. If the dislocations occurred during everyday activity, then first of all, the implants malposition or soft tissues insufficient tension should be suspected. It is in contrast to an injury that was adequate in strength (fall from a height, road accident, etc.) [23]. In the posterior dislocations, the limb is shortened, it can be bent at the level of the pelvis, adducted and rotated inward. In the anterior dislocations, the limb is also shortened, it can be bent, but abducted and rotated outward [23, 104].

The evaluation of the placed implants, their type, size, positioning is important. If possible, it is desirable to clarify the intraoperative features [23, 104]. It is necessary to make a general X-ray in the antero-posterior plane capturing both joints. The stability of the implants and possible fracture should be assessed [23, 103]. Evaluation should pay attention to head centering, Shenton line rupture, and the appearance of the lesser trochanter that is obscured in internal rotation, and thus dislocations occurs posteriorly [103]. To clarify the direction of the |dislocations anteriorly or posteriorly, a lateral X-ray can be taken [23, 103]. For a more detailed assessment of a possible fracture and positioning of implants, some authors recommend performing CT [23, 103]. As a rule, MRI in the mode of metal artifact reduction sequence (MARS) is not used [103, 105]. Although in some cases only it allows excluding the separation of abductors, rupture of short rotators and capsule [105].

Conservative treatment

As a rule, at the first dislocations, if there is no fracture and/or signs of instability of the endoprosthesis components, the closed reduction is performed, and then the patient is treated conservatively [23, 104]. It is important to determine what dislocations occurred, anterior or posterior, since the reduction technique is different for them [106]. Ideally, the reduction should be performed under fluoroscopic guidance with sedation or general anesthesia [106]. It is recommended that propocol for sedation should be used, since it is not only more preferable in terms of quick recovery compared with etomidate and opiates/benzodiazepines, but also allows for deeper sedation and muscle relaxation [107]. After successful closed reduction, some studies recommend limiting the axial load for 24 h [106]. It is recommended gradually increasing the range of motion after reduction under the supervision of medical personnel and avoiding extreme positions in the range of motion for 3 months [106].

The imposition of a coxitis plaster cast (long or shortened above the knee) is almost never found in modern publications and in practice, although in the 1960s – 1970s it was used almost always [1, 2, 3]. Abduction cushions and braces are often recommended, but the effectiveness of the latter is highly questionable, and they can cause very serious discomfort [108]. For example, S.A. Brennan et al. reported 69.2% of re-dislocations after using a brace, which is not at all different from the rate of re-dislocations without a brace (68.9%) [12].

Among our 44 patients with dislocations (10 patients with antero-lateral approach, 34 patients with a posterior approach), conservative tactic were successful in 5 (50%) patients with antero-lateral approach and in 19 (55.6%) patients with a posterior approach. These results contrast somewhat with those of S.A. Brennan et al, who argued that with early first dislocations, the likelihood of recurrent dislocations was less if the surgery was performed through the antero-lateral approach, compared with the posterior or pertrochanteric approach [12].

At the first dislocations, in any case, in our opinion, it is necessary to try to predict the risk of subsequent dislocations, taking into account the timing of the first dislocations, approach and all other risk factors described above, and use the resulting prognosis when informing the patient. If at the first dislocations there is a fracture or displacement of the components of the endoprosthesis, the appropriate surgical tactics are used.

Classification of surgical tactics

In the case of recurrent dislocations, the decision about surgery can be difficult, especially if there is no gross malposition. In the literature, there is no clear data on after what dislocations, the further conservative attempts can be successful. We believe that the second dislocations very likely to indicates that the dislocations will continue to recur. The decision about revision is made based on many characteristics and patient choice. At least in many studies, the authors report that the average number of dislocations before revisions varies from 3 to 5 or more, and in some cases the number of dislocations is dozens. This fact must be used in the conditions of medical care quality criteria system being introduced in our country, because if it is written in the clinical guidelines that a revision is indicated for the second dislocations, then we will not take into account the real clinical practice and unreasonably put the medical staff at risk.

Revision planning should be thorough, taking into account all risk factors to identify the specific etiology of dislocations. There are several classifications of dislocations, but they are very similar to each other [6, 109]. For example, G.D. Wera et al., on the basis of 75 revisions for dislocations, proposed to distinguish 6 types: 1) malposition of the acetabular component; 2) malposition of the stem; 3) abductors deficiency; 4) impingement; 5) wear of the liner; 6) unclear etiology [109].

It can be noted that this classification does not take into account the spinal-pelvic imbalance, to which we paid much attention above, and according to the proposal of A.M. Saiz et al. [45], it can be distinguished into a new 7th type (Table 3).

The anteversion angle from the antero-posterior X-ray can be measured as follows. The anterior-posterior plane of the short axis (CD) and long axis (AB) of the cup are measured. The sine to the minus one power of the CD/AB ratio will give us the value of the angle anteversion in degrees (Fig. 2). The sine to minus the first degree is called the arcsine. You can calculate its anteversion value in degrees without unnecessary hassle in any Internet calculator by typing “calculate arcsine” into the search box and entering the resulting ratio CD/AB, ordering the answer format in degrees. Of course, the anteversion angle can also be measured on a computed tomogram. Calculating the exact anteversion angle is especially important if we have a dislocated patient with a liner without a lip. In this case, we will be able to accurately calculate the angle of the new anteversion before the surgery in the case of a simple replacement of the old liner with a lipped liner. In order to understand whether the new anteversion is enough, it is also necessary to analyze the anamnesis. If dislocations occur during everyday activities with a small amplitude, then, most likely, it will not be possible to achieve stability with a small increase in anteversion (especially with an initially close to the recommended anteversion). In addition to the anamnesis, if you decide on the sufficiency of replacement the old liner with the lipped liner, it is necessary to assess the spinal-pelvic imbalance and the "functionally safe zone".

Table 3

Tactics in dislocation according to A.M. Saiz et al. [45], G.D. Wera et al. [109], modified by the authors of this article

Type	Etiology	Diagnosis	Treatment
1	Cup malposition	Antero-posterior X-rays/measure inclination and anteversion*	Lipped liner*; cup revision
2	Stem malposition	CT of the knee and the hip, measurement of stem anteversion	Stem revision
3	Abductors deficiency	MRI in MARS mode, Trendelenburg's test	Constrained liner, dual mobility, abductors reconstruction
4	Impingement	Intraoperative assessment of the signs of impingement and its localization before removal of the implants; assessment of impingement in extreme range of motion	Elimination of impingement causes
5	Liner wear	Decentration of the head according to X-ray in antero-posterior plane	Liner replacement; curettage and bone grafting of osteolysis zones
6	Unclear etiology	No clear reason for the dislocation	Dual mobility
7	Spine-pelvic imbalance	Functional lateral X-rays in a sitting, standing position, “step up a step”, assessment of pelvic inclination (hypo-, hypermobile pelvis, normal inclination), associated assessment of cup position in the context of “functionally safe zone”	Anteversion and inclination of the cup in the "functionally safe zone"

* See text below for explanations on measuring anteversion.

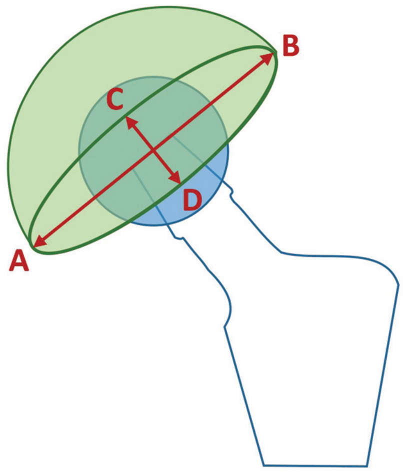

Fig. 2. Anteversion measurement. Anteversion angle = sin−1 (CD/AB) or arcsin (CD/AB). In this case, CD/AB = 0.287 and, respectively, an anteversion angle = 16° (by A.P. Sereda).

The lipped liner can reduce the risk of dislocations both after primary and after revision HA [27, 104]. According to G.M. Alberton et al., such liners reduced the rate of dislocations by 2.2 times after isolated cup replacement and 4.4 times with combined cup and liner replacement. In their opinion, the greater reduction in the risk of dislocations in the cup and stem replacement means that this traumatic operation leads to greater problems with soft tissue tension and muscle integrity, which requires additional stabilization measures in the form of a lipped liner placement. However, if re-revision was performed for dislocations, then the failure rate was the same when replacing only the stem, only the cup, or the stem and the cup together (7.1%; 9.0% and 7.3%, respectively; p = 0.61) [27].

In rare cases, completely original methods of stabilization can be found. For example, S. Kamath and A. Campbell for stabilization screwed with two screws to the cement cup a sector from another polyethylene cement cup [110].

In surgery with the liner changing, it is worth increasing the head diameter, if possible, but we do not recommend an isolated increase in the head diameter (up to 36, 40 mm) without correcting other reasons. We also do not recommend increasing the offset by changing the head as the only measure. J. Parvizi et al. reported on the replacement of a bipolar endoprosthesis with a correspondingly larger head diameter in 27 patients with chronic dislocations, which was effective in 81% of cases [111].

During revision, of course, the already described maneuvers for enhanced suturing with posterior approaches [93, 94], plastics with synthetic materials [95], greater trochanter trochanteric advancement are important and take place [96]. In theory, in some rare cases, arthroscopic capsule reconstruction is promising [97].

Great care should be taken when using constrained liners. The rate of revisions with these liners for other reasons is very high (16–29%) [76, 112]. The constrained liner cannot compensate for inadequately positioned implants. We will get another failure when the liner itself [45] or the liner with the cup breaks out.

Dual mobility

As we wrote above, dual mobility can reduce the rate of dislocations after primary THA [11], which makes it the method of choice for the patients at high risk.

There are more than two dozen studies examining the effectiveness of double mobility in revision for dislocations. These works are very heterogeneous in design and describe a maximum of several dozen cases with various results. We will not dwell on them in detail, since there is a large French multicenter study of 3,473 revision cases (using dual mobility during the first revision for dislocations), which gave a phenomenally low failure rate of 0.43% with a follow-up of 5 to 11 years [67]. Currently, dual mobility is perhaps the most reliable stabilization option.

Girdlestone surgery

In the most severe cases of recurrent dislocations, a desperate surgery by Girdlestone (resection arthroplasty) can be performed. This is the last measure that can be considered after repeated unsuccessful revisions in the patients with significant comorbidity, in whom traumatic revisions with significant defects in the muscles and the proximal femur are dangerous [66]. Usually, the resection THA is performed for chronic infection and sepsis [113, 114]. This operation, which obviously does not restore the function of the joint, nevertheless completely eliminates dislocations and allows the patients to walk with additional support and be independent. However, the literature describes cases when dissatisfied patients after Girdlestone surgery underwent conversion to a megaendoprosthesis [115, 116].

Conclusion

Dislocations after THA are still a relevant problem, although the rate of these complications has been decreasing in recent decades. The etiology of dislocations after primary THA is multifactorial, and in assessing each patient, all risk factors should be considered, including the patient's characteristics and factors related to the surgeon. The boundary between patient-related and surgeon-related factors is gradually blurring, especially in the patients with spinal pelvic imbalance. The Lewinnek "safe zone" concept is being replaced by the "functionally safe zone" paradigm. The strategy for reducing the risk of dislocations consists of carefully planning the operation, considering all risk factors, understanding the biomechanics of the hip and applying adequate appropriate measures to correct the etiological factors, if possible, or compensate them through other techniques. If dislocations occurred, the conservative tactics may be effective. At the same time, it is important to analyze the causes of dislocations, which, when repeated, requires the revision surgery.

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Authors' contribution

Andrey P. Sereda – research design, literature review, data analysis, text preparation, correction and final editing.

Sergey M. Smetanin –data statistical processing, literature review.

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