ОГЛЯДИ ТА РЕЦЕНЗІЇ

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The impact of hip-spine relations on the results of total hip arthroplasty (literature review)

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Spine balance can alter THA outcomes, but the exact mechanism is not yet well recognized. We aimed at bridging the gap between hip and spine surgeons with an up-to-date analysis of the best available literature review concerning to data as for total hip arthroplasty results of those patient with concomitant spine disorders. In total hip arthroplasty accurate acetabular cup placement is essential for impingement free and stable range of motion. For decades, hip surgeons have relied on traditional safe acetabular zones to reduce prosthetic instability. Nevertheless, hip dislocation is one of the most common complications following total hip arthroplasty. Numerous studies have shown that patients with abnormal spinopelvic mobility due to degenerative spinal diseases and after spinal fusion surgery had an increased rate of dislocations after THA. In our review we described the main spine-pelvic parameters, such as pelvic tilt, sacral slope, pelvic incidence, lumbar lordosis etc. and spinopelvic motions and how they can change in standing and sitting postures. Measurements of these parameters are necessary for presurgical planning before hip arthroplasty especially those patients who had previously made spine fusion. A review of literature shows that sagittal pelvic kinematics, but not the pelvic incidence, influences the risk of prosthetic impingement or dislocation. Pelvic position is dynamic during gait and other daily living activities. Variations in anteroposterior pelvic tilt affects the resulting spatial orientation of the acetabulum. Recommendations for cup positioning are switching from a classic Lewinneck safe zone to a patient-specific approach, with the standing cup orientation giving way to a new parameter of interest: the functional orientation of the cup. Thus, functional cup anterversion should be taken into consideration. Abnormal spinopelvic mobility is a risk factor for THA dislocation. Thus patients with combined spine and hip pathology are at higher risk for further complications and they should be identified and screened more carefully.

Хребтовий баланс може змінити результати тотального ендопротезування кульшового суглоба (ТЕКС), але точний механізм впливу недостатньо вивчений. Мета. Об'єднати працю хірургів-ортопедів і вертебрологів шляхом аналізу сучасної літератури щодо загальних результатів ТЕКС у пацієнтів зі супутніми захворюваннями хребта. ТЕКС має важливе значення для вільного та стабільного руху. Протягом десятиліть ортопеди орієнтуються на традиційні безпечні параметри ацетабулярної зони, щоб зменшити нестабільність ендопротезів. Проте вивих головки ендопротеза є одним із найпоширеніших ускладнень після ТЕКС. Визначено підвищений рівень вивихів у пацієнтів з аномальною рухомістю у хребтово-тазовому сегменті внаслідок дегенеративних захворювань і після спондилодезу хребта. У роботі описано основні хребтово-тазові параметри (нахил таза, крижовий нахил, поперековий лордоз тощо), рухи у хребті та суглобах і їхні зміни в положенні стоячи та сидячи. Вимірювання цих параметрів необхідне для хірургічного планування перед ТЕКС, особливо тим пацієнтам, яким раніше виконали спондилодез. Встановлено, що сагітальна кінематика таза впливає на ризик виникнення імпінджменту або вивиху ендопротеза. Положення таза є динамічним під час ходьби й інших повсякденних дій. Варіації передньо-заднього нахилу таза впливають на отриману просторову орієнтацію кульшової западини. Рекомендації щодо позиціонування чашки — це перехід від класичної безпечної зони Левінека до індивідуального підходу для пацієнта з урахуванням орієнтації кульшової западини в положенні стоячи, що поступається місцем новому параметру — функціональній орієнтації чашки. Слід ураховувати функціональне положення западини за ендопротезування. Аномальна рухомість хребтово-тазового сегмента є чинником ризику вивихів після ендопротезування. Тобто пацієнти з поєднаною патологією хребта та кульшового суглоба мають більший ризик ускладнень, тому рання діагностика й ретельніше обстеження для них є доцільним.

Ключові слова. Хребтово-тазові взаємовідношення, сагітальний контур хребта, ендопротезування, вивих ендопротеза.

Key words. Spine-pelvic relations, sagittal alingement, hip arthroplasty, dislocation

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Introduction

Spinopelvic mobility represents the complex interaction of hip, pelvis, and spine. Understanding this interaction is relevant for both arthroplasty and spine surgeons, as a predicted increasing number of patients who suffer from hip and spinal pathologies simultaneously. Spinopelvic mobility can be affected by degenerative diseases of the spine and hip and by spinal fusion surgery. In an aging society, the prevalence of degenerative musculoskeletal diseases increases. As a result, there will be more patients with concurrent degenerative spine and hip pathologies, who will require spinal fusion and total hip arthroplasty (THA) [1, 14].

THA is a very successful medical intervention. However, complications such as THA dislocations may occur. The incidence of this complication after primary THA is reported to be approximately 1.5 % to 4.8 % [3–5]. Approximately 50 % of dislocations occur within the first 3 months after the primary procedure [6].

Within the first 2 years postoperatively, dislocation is the most common cause for revision surgery [7]. Unfortunately, revision surgery to treat hip instability, ranging from «simple» head and liner exchange to all-component revision or use of constrained devices, has met with variable success [8, 9].

Thus, spine disease can decrease motion, through degenerative disease or surgical fusion, and cause abnormal spinopelvic posture due to compensatory pelvic rotation in order to maintain sagittal balance with efficient posture. The lack of proper spinopelvic motion may jeopardize the functional position of the acetabulum. Techniques and physiologic markers normally used by the hip surgeon to access relative safe zone cup placement may not be ideal for degenerative spine patients. Numerous studies have demonstrated that THA patients with concomitant spinal deformity experience episodes of instability and dislocation at disproportionately high rates despite traditional, safe zone cup placement [2, 10–12].

As a result, there has been a recent increase in interest to characterize spinopelvic motion abnormalities and elucidate their impact on total hip arthroplasty outcomes.

Studies data as for THA outcomes at combined spine and hip pathology

A considerable number of THA dislocations without known cause awaked an increased attention to abnormal spinopelvic mobility at THA, especially on cup positioning. Focusing on patients with suspected abnormal spinopelvic mobility due to degenerative spinal diseases and after spinal fusion surgery, an increased incidence of dislocations in THA of 7.4 % to 8.3 % was reported. Malkani found hip instability to be the most common reason for failure leading to revision surgery in patients with lumbar fusion before THA. In this study, the risk of THA dislocation in patients with lumbar fusion before THA was found to be 7.4 %, compared to 4.8 % in those without fusion [13–15].

One study to date has described increased THA prosthetic-related complications and revision in patients with prior lumbar spinal fusion, from 6 months to 2 years following THA when compared to the general Medicare database [16]. Buckland and Sing et al. proved the correlation of an increased dislocation rate after THA with a larger number of spinal fusion levels. D. J. Blizzard et al. [17]. using the same Medicare database but selecting for lumbar spine disease rather than lumbar fusion procedures similarly found an increase in prosthetic joint dislocation and revision THA at 2 years when compared to the general Medicare patient data. Gausden reported history of spinal fusion as the strongest independent predictor of dislocation in THA [18]. A meta-analysis including six studies revealed a twofold increased risk of dislocation and a threefold increased risk for revision surgery in patients with spinal fusion [19]. Whereas D. O. Perfetti et al. reported spinal fusion patients to be seven times more likely to experience THA dislocation [11].

The impact of spinopelvic imbalance is particularly profound in THA late dislocations. N. Heckmann et al., reported that 90 % of their late dislocations (defined as > 1 year) in patients who had spinopelvic imbalance [20].

In summary, restricted spinopelvic mobility, regardless of whether it is due to spinal fusion or degenerative, has an influence on the alignment of the acetabulum and is considered to increase risk for dislocations in THA. It should be mentioned that spinopelvic imbalance does not necessarily lead to dislocation, as the majority of THA patients remain without complications despite progressive spine degeneration, as it was shown in 10 year follow up study on THA patients which found 62 % had abnormal spinopelvic motion [21].

Spinopelvic parameters

Spinopelvic parameters are dynamic and change in different positions to ensure movement and posture. In order to understand and define the spine — hip relationship (SHR), it is important to understand the significance of the spino-pelvic parameters, such as sacral slope (SS), pelvic tilt (PT), pelvic inci-

dence (PI), lumbar lordosis (LL) and the C7 plumb line (C7pl) (fig. 1). SS, PT and LL are «functional parameters», as their value varies with body position; PI is a «morphological parameter» as it is constant for an individual.

H. Ike et al. provided an excellent list of many of the common terms that are used in the literature and defined them [22]. The authors of this review have chosen additional terms that are used.

The term pelvic tilt (PT) used in arthroplasty literature for hip navigation is the rotation of the pelvis in the sagittal plane as measured by the angle formed between the coronal plane and the anterior pelvic plane (APP) which is defined by a line from the anterior superior iliac spine (ASIS) to pubic symphysis. APPt can be performed both anteriorly and posteriorly. Posterior APPt describes a backward motion of the pelvis and is the equivalent motion to pelvic retroversion. With posterior pelvic tilt, or pelvic retroversion, the functional position of the acetabular cup becomes more anteverted. Pelvic tilt varies according to posture, age, and other factors and posterior pelvic tilt typically increases with age. This progression is usually gradual, due to the loss of lumber lordosis, weakness of the back muscles, flexion contracture of the knee, and other factors [23].

Sacral Slope is an angle between a horizontal line and the sacral endplate.

The sum of pelvic tilt and sacral slope SS is the pelvic incidence (PI), a position-independent interindividual different anatomical parameter (PI = SS + (s PT)). When changing position, the change in pelvic tilt (APPt and (s)PT) correlates inversely with the change in sacral slope, and this correlates directly with lumbar lordosis to maintain an upright posture. Pelvic incidence (PI) determines the degree of femoral flexion required to sit. The lower the PI, the less the pelvis will tilt so greater femoral flexion is required and thus higher risk for bony impingement and dislocation [24].

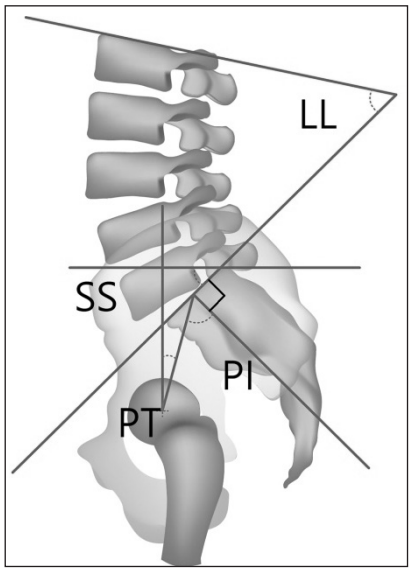

Fig. 1. The main spino-pelvic parameters: the sacral slope SS; the pelvic tilt PT; the pelvic incidence PI; lumbar lordosis LL

Normal spinopelvic motion

A normal SHR occurs when a healthy flexible lumbar-pelvis complex interacts with healthy flexible hips. Normal standing posture consists of slight anterior pelvic tilt with a mean sacral slope of 40° and adequate physiologic lumbar lordosis (LL) to achieve sagittal balance. Normally, from standing to sitting, adaptation processes are performed: the sacrum moves posteriorly (pelvis is retroverted), the lumbar lordosis decreases, and the acetabular anteversion increases. The posterior tilt of the pelvis reduces the sacral slope to the same amount. So, as it was mentioned for each degree 1.0° of posterior pelvic movement, there is an increase of 0.7° to 0.8° in aceabular anteversion. With 20° of posterior pelvic tilt, the hip needs to only flex 55° to 70° to achieve proper sitting posture (fig. 2) [25].

When changing position from standing to supine, the pelvis moves anteriorly and leads to a reduction in acetabular anteversion. The anterior tilt of the pelvis is performed to a smaller extent than the posterior tilt.

Abnormal spinopelvic motion

Degenerative spinal changes can lead to a sagittal imbalance.

Fig. 2. Normal spinopelvic motion with an increase in posterior pelvic tilt (APPt line) and decrease of sacral slope (SS) and lumbar lordosis (LL) in lateral standing (a) and sitting (b) radiographs [26]

Spine mobility is limited by spinal fusion or degenerative changes (lumbar stiffness) is associated with loss of posterior tilt. The normal spine can accommodate a mean posterior APPt of 20° (ΔAPPt or ΔSS of 20°) when transitioning from standing to sitting. Spinal stiffness is defined as ΔSS less than 10° [27]. Patients with spinal stiffness cannot increase their functional acetabular anteversion when changing position for sitting, instead trying to compensate with femoral hyperflexion at the risk of anterior impingement and consequent posterior dislocation (fig. 3).

Spinal sagittal imbalance occurs as the aging spine becomes progressive more kyphotic due to degenerative disease. In order to regain sagittal balance compensatory mechanisms are employed which include obligatory posterior APPt. The limit of posterior APPt is dependent on individual PI and hip extension reserve [29]. Especially, hip extension can be affected by hip osteoarthritis. So, while standing, the acetabulum is functionally anteverted so there is a risk for posterior impingement and subsequent anterior dislocation with hip extension [30].

Pelvic tilt and cup orientation

So, it is likely that most of the atraumatic dislocations that happen with modern implants are the result of atypical pelvic kinematics. In total hip replacement, achieving ideal orientation of the cup is essential in reducing edge loading and articular impingement, which would otherwise lead to accelerated wear, squeaking, and increased dislocation risk [24, 31]. Lazennec et al. pioneered the study of the hip and spine relationship in 2004 has introduced the idea of a «functional» acetabular cup position in the sagittal plane [25]. This parameter allows us to understand the pathophysiology of prosthetic dislocation and to explain why patients with normal standing cup orientation sometime dislocate, while other patients with abnormal ones do not. The fact that functional cup orientation is likely related to pelvic kinematics, which in turn is mostly influenced by lumbar mobility [32].

When considering dynamic spinopelvic motion that changes with position, static versus functional position also needs to be understood. Various guidelines have been proposed for the orientation of the acetabular component in total hip arthroplasty. The most commonly cited guidelines date back to 1978. When arthroplasty surgeons still focus on placing components into the ideal Lewinnek Safe Zones (LSZ) as determined by inclination of 40° ± 10° and anteversion of 15° ± 10° in the static intraoperative supine or lateral position [33]. However, various authors have challenged the relevance of these zones and highlighted the lack of consensus between various guidelines. In a series of more than 9 000 THAs, M. P. Abdel et al. showed that more than half of the dislocations occurred with acetabular components which were placed within the safe-zone [10]. Stability of hip implant is likely multifactorial and the ideal cup position for some patients may lie outside the Lewinnek safe zone. However, dislocation, edge-loading and impingement more commonly occur during activities when the position of the pelvis, and thus the acetabular component, could be significantly different to that seen with static, non-functional imaging.

There is a lack of data as for the dynamic postural changes that happen when the patient is standing or sitting. And the focus should be placed on the «functional» position of the components that takes into

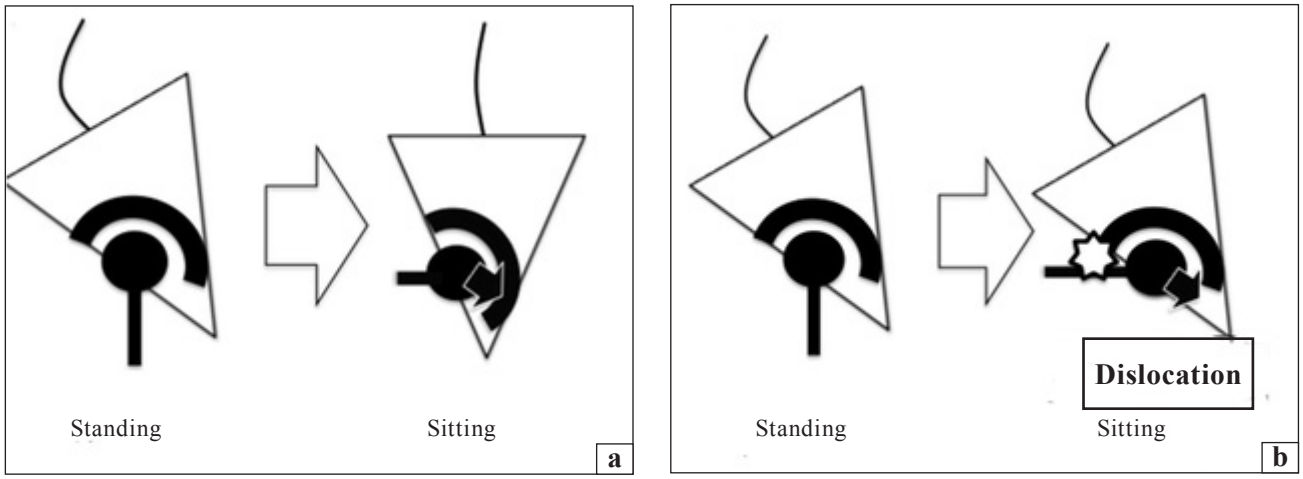

Fig. 3. In the healthy person, pelvis shifts to retroversion in sitting position (a). On the other hand, in the patients with spinal fusion with pelvic fixation, pelvis cannot shift to retroversion and stays anteverted. In this case the neck impingement occurs at the anterior edge of the cup, then femoral head is dislocated posteriorly (b) [28]

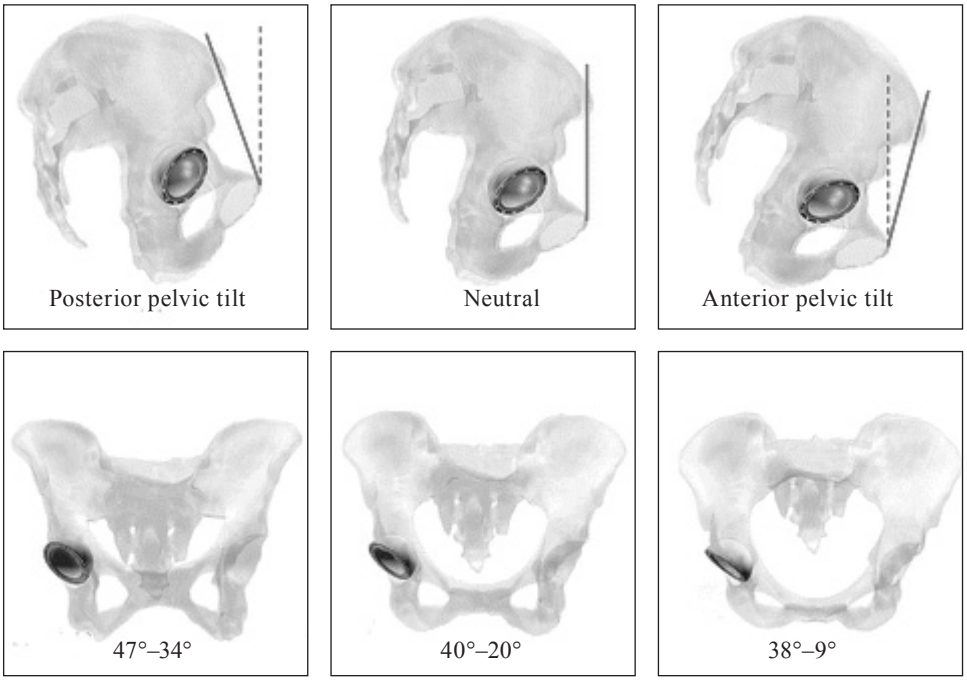

Fig. 4. Pelvic tilt and its effect on functional orientation of the cup at total hip arthroplasty [37]

account the functional motion of the pelvis. Pelvic position is not static, but rather dynamic during gait and other daily living activities. Variations in anteroposterior pelvic tilt will affect the resulting spatial orientation measurement of the cup (fig. 4). In one of the studies the authors studied the effect of anteroposterior pelvic tilt on acetabular component position in THA. Anteroposterior pelvic tilt was measured in 619 hips. The hips were divided into five groups. Of the 619 hips measured, 8.6 % had no anteroposterior pelvic tilt, 40.4 % had posterior pelvic tilt of 1° to 9°, 12.6 % had posterior pelvic tilt of 10° to 25°, 33.6 % had anterior pelvic tilt of 1° to 9°, and 4.8 % had anterior pelvic tilt of 10° to 20°. An anteroposterior pelvic tilt of 1° led to an approximate 0.8° change of functional cup anteversion [34, 35]. These data confirmed previously published study by B. Lembeck et al. [36]. It is important to note that, with every 1° of posterior tilt, patients show an increase in acetabular anteversion of 0.7° to 0.8° and, thus, functional anteversion changes.

Conclusions

Spinopelvic mobility is a substantial factor to be assessed when performing THA. Abnormal spinopelvic mobility is a risk factor for THA dislocation. This is relevant not only for arthroplasty surgeons, but also for spine surgeons, as the combination of osteoarthritis and spinal pathologies are increased.

THA positioning according to LSZ will be adequate for most people. Patients with combined spine and hip pathology at high risk should be identified and screened more carefully, especially in patients with suspected limited spinopelvic mobility, such as history of lumbosacral fusion, kyphotic standing posture, severe spinal degenerative disease, hip flexion contractures, and history of THA dislocation and revision surgery. Spinopelvic measurements should be done in both sitting and standing positions.

Most arthroplasty surgeons focus on the acetabular component positioning according to the static position of the pelvis. However, the functional position should be used instead.

Conflict of interest. The authors declare the absence of conflict of interest.

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