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Adverse spinopelvic mobility in patients undergoing total hip arthroplasty is associated with high mobility of the hip in a flexed seated position

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Abstract

Purpose: Adverse spinopelvic mobility from a standing to a flexed seated position of more than 20° of the spinopelvic tilt (ΔSPT) has been shown to have a high risk of dislocation. If hypermobility of the hip analysed with the pelvic femoral angle (ΔPFA) has a high risk of impingement, the correlation between the range of motion of the hip from a standing to a flexed seated position and its implication in adverse spinopelvic mobility has not been described.

Methods: A series of 337 patients treated with primary THA underwent lateral x-ray in standing and flexed seated positions to analyse ΔSPT, ΔPFA and spinopelvic parameters. The objectives were to establish a ΔPFA threshold associated with a ΔSPT ⩾20° and to subsequently investigate its influence in conjunction with spinopelvic risk factors on the occurrence of adverse spinopelvic mobility.

Results: The area under the curve was 0.904 (95%CI, 0.864–0.945) for ΔPFA to predict ΔSPT ⩾ 20°; it was predicted by ΔPFA ⩾ 95° with a sensitivity of 91.7% and a specificity of 74.4% at the Youden optimal threshold. Patients with a ΔSPT < 20° (277 patients) had a mean ΔPFA of 83° compared to 110° if ΔSPT ⩾ 20° (60 patients) ($p < 0.001$). Patients with a ΔPFA < 95° (203 patients) had a mean ΔSPT of −6° compared to 18° if ΔPFA ⩾ 95° (134 patients) ($p < 0.001$). ΔPFA ⩾ 95° rates were 95% (57/60) and 27.8% (77/200) in patients with ΔSPT ⩾ 20° and ΔSPT < 20°, respectively (OR 49.35; CI, 15.01–162.28; $p < 0.001$).

Conclusions: High mobility of the hip (ΔPFA ⩾ 95°) seems to be a necessary condition for adverse spinopelvic mobility. A preoperative analysis of patients with lower hip mobility, associated with spinopelvic risk factors, might identify patients with abnormal spinopelvic mobility after the restoration of femoral flexion.

Trial registration: IDRCB 2023-A01390, CNIL MR004 2225508 (07/06/2023), retrospectively registered.

Keywords

Hip flexion, spine hip relationship, spinopelvic mobility, impingement, total hip arthroplasty

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Introduction

The correct acetabular cup position is 1 of the most important variables for successful total hip arthroplasty (THA).[1] Mechanical alignment, which is considered the gold standard,[2,3] is independent of the patient's individual anatomy. New techniques that adapt to interindividual anatomy are being developed, such as patient-specific orientation (PSO), which involves adapting to the individual's spine-hip relationship (SHR) to prevent poor interaction of functional components (edge loading, articular impingement).[4] Impingement is a frequent cause of poor outcomes of THA,[5] causing instability, accelerated wear, unexplained pain,[6,7] and squeaking with ceramic-on-ceramic hips.[8]

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The position of the pelvis may vary significantly and rotate anteriorly from standing to sitting by ⩾13° in 11% of patients with a risk of anterior impingement and by >13° from a supine to standing position in 6% of patients with a risk of posterior impingement.[9] A 10° change in pelvic rotation changes the anteversion of the component by 7° [10], and an adverse spinopelvic mobility (SPM) with a change in spinopelvic tilt (SPT) from a standing to a flexed seated position (ΔSPT) of more than 20° has been shown to be associated with a high risk of impingement and dislocation.[11,12]

When assessed individually, risk factors for ΔSPT ⩾ 20°, such as standing SPT, lumbar flexion (LF) and pelvic incidence (PI)-lumbar lordosis (LL) mismatch,[13] help clinicians to predict patients who need an adapted cup position.[11,14]

Furthermore, hip flexion is a very important factor, and hypermobility of the hip analysed with the pelvic femoral angle (PFA) in a relaxed seated position has a high risk of impingement.[15] The combined sagittal index uses this angle to predict the safe orientation zone of the cup before THA.[16,17] However, the relaxed seated position appears to overpredict the presence of a stiff spine,[18] and if the flexed seated position should be used to assess a patient's spine mobility prior to THA, the correlation between the range of motion of the hip from a standing to a flexed seated position and its implication in adverse spinopelvic mobility has not been described. Indeed, if hip stiffness limits anterior rotation of the pelvis, particularly in patients with arthritis, surgery may allow for an increase in femoral flexion. It seems important to identify patients whose unfavourable lumbopelvic kinematics, masked by hip stiffness, may reveal itself after hip replacement by defining a threshold below which abnormal spinopelvic mobility cannot be expressed.

The objectives of this study were as follows: to establish a ΔPFA threshold associated with a ΔSPT ⩾ 20° and to subsequently investigate its influence in conjunction with spinopelvic risk factors on the occurrence of adverse spinopelvic mobility.

Material and methods

Participants

A consecutive series of 337 patients who underwent primary THA for hip osteoarthritis between March 2019 and May 2023 were included. The mean patient age was 64 years (range 24–82 years). There were 136 men (40.4%) and 201 women (59.6%), with 185 right hips (54.9%) and 152 left hips (45.1%). Preoperative planning using Optimized Positioning System™ (OPSInsight, Corin, Cirencester, UK) was implemented for cementless THA with ceramic-on-ceramic bearings (Meije Dynacup, Corin, Cirencester, UK). 10 patients (2,8%) were excluded due to lack of x-ray quality. This study was approved by the local ethics committee with patients providing informed consent.

2 lateral x-rays were captured for each patient between 3 months and 6 weeks before surgery: 1 of the upper body while the patient was standing in a relaxed posture with the feet shoulder-width apart and 1 while the patient was in a flexed-seated position, with the femurs parallel to the floor.[19]

Spinopelvic and pelvic mobility parameters

The measurements obtained from lateral x-rays were the standing and flexed-seated LL and standing and flexed-seated SPT (Figure 1).[13] Anterior rotation of SPT was assigned a positive value and posterior rotation a negative value. An increase in SPT denotes anterior rotation of the pelvis that is equivalent to anteversion, which decreases PT. The measurement taken from the bony landmarks on the computed tomography (CT) scan was the PI. We investigated the LF, as defined as the difference between the standing and flexed-seated LL and the PI-LL mismatch, as defined as the difference between PI and LL in the standing position. Pelvic mobility was measured as the difference between the standing and flexed-seated SPT (ΔSPT). All imaging findings were analysed by 2 independent engineers.

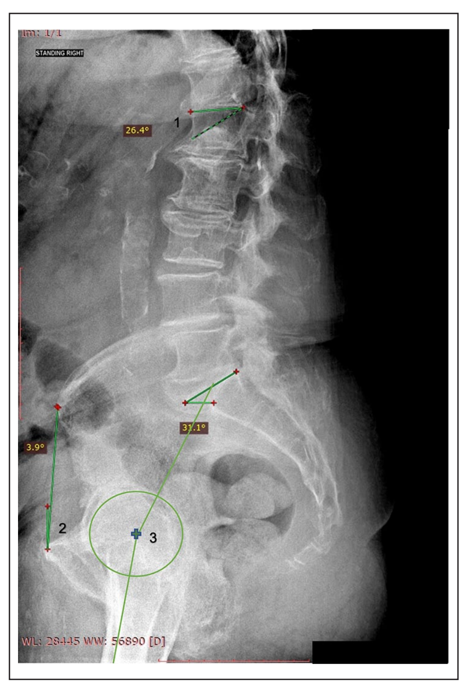

Figure 1. Radiological measurement of spinopelvic parameters. Radiograph in a standing position. The angle 1 represents the lumbar lordosis between the superior endplate of L1 and S1, the angle 2 represents the spinopelvic tilt and the angle 3 represents the pelvic femoral angle.

A senior surgeon measured the pelvic femoral angle (PFA) in a standing and flexed-seated position, which is the angle that is formed by making a line from the centre of the S1 end plate to the centre of the femoral head and making a second line parallel to the femoral diaphysis (Figure 1). Femur mobility was measured as the difference between the standing and flexed-seated PFA (ΔPFA). 3 surgeons measured the ΔPFA in a random selection of 100 patients to assess the reliability of measurements taken by different observers.

Outcome

We defined high mobility of the hip with a threshold regarding adverse spinopelvic mobility and then divided the population according to this threshold.

The outcome of interest was adverse spinopelvic mobility, as defined as ΔSPT ⩾ 20° between the standing and flexed-sitting positions.[7] The femoral head diameter was determined according to the size of the planned cup, and the femoral stem and head offset were simulated to match the patient's native femoral anteversion and native femoral offset.

We analysed risk factors for adverse spinopelvic mobility, as follows: SPT ⩽ −10°, LF ⩽ 20° and PI-LL ⩾ 10°in relation to hip mobility (ΔPFA).[13,20] We compared the rate of adverse spinopelvic mobility (ΔSPT ⩾ 20°) based on the presence or absence of each risk factor in the study population and then between the 2 groups divided according to the hip mobility threshold determined previously.

Statistical analysis

Continuous variables are described using means and medians and interquartile ranges. We compared means and proportions between groups using Fisher's exact test or chi-square test. We employed receiver operating characteristic curves to assess the ability to predict ΔSPT ⩾ 20° according to ΔPFA. The area under the curve and 95% confidence intervals (CIs) were calculated. To assess agreement between the 3 observers, intraclass correlation coefficient (ICC) estimates and their 95% confidence intervals were calculated based on a single-rater, absolute agreement, 2-way random effect model; ICC values <0.5, between 0.5 and 0.75, between 0.75 and 0.9, and >0.9 were considered poor, moderate, good, and excellent reliability, respectively. We used R (version 4.0.0, R Foundation for Statistical Computing) and EasyMedStat (version 3.27) for the analyses, and probability values <0.05 were considered significant.

Results

Analysis of ΔPFA and relationship to abnormal SPM

Descriptive anatomic measurements for the whole study cohort are provided in Table 1. There was excellent agreement between ΔPFA measurements (ICC 0.91; 95% CI, 0.87–0.94; $p < 0.001$).

Table 1. Baseline characteristics of the patients.

Baseline characteristics	*n* = 337
Age (years), mean (range)	64 (24/82)
Women, No. (%)	201 (59.6)
Spinopelvic parameters	
Pelvic incidence (°), mean (range)	55.3 (24/99)
Lumbar lordosis (°), mean (range)	5.4 (22/93)
Standing SPT (°), mean (range)	0 (−31/23)
Lumbar flexion (°), mean (range)	50.7 (15/92)
PI-LL mismatches (°), mean (range)	−2.7 (−39/35)
ΔSPT (°), mean (range)	3.3 (−55/41)
Standing PFA (°), mean (range)	190.8 (142/219)
Seated PFA (°), mean (range)	102.9 (59/174)
ΔPFA (°), mean (range)	96.1 (2/139)

SPT, spinopelvic tilt; PI, pelvic incidence; LL, lumbar lordosis; PFA, pelvic femoral angle.

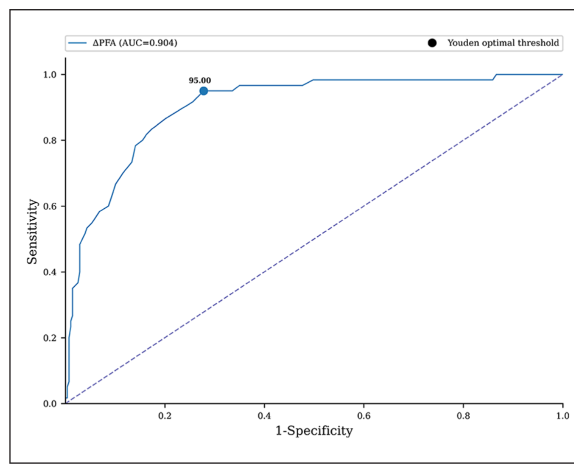

Figure 2. Performance of an optimal threshold value for ΔPFA at 95° regarding abnormal SPM. The panel shows the ROC curve of the model and the Youden optimal threshold.
AUC, area under the curve.

The area under the curve was 0.904 (95% CI, 0.864–0.945) for ΔPFA to predict ΔSPT ⩾ 20° and was predicted by ΔPFA ⩾ 95° with a sensitivity of 91.7% and a specificity of 74.4% at the Youden optimal threshold (Figure 2).

Patients with a ΔSPT < 20° (277 patients) had a mean ΔPFA of 83° compared to 110° if ΔSPT ⩾ 20° (60 patients) ($p < 0.001$). Patients with a ΔPFA < 95° (203 patients) had a mean ΔSPT of −6° compared to 18° if ΔPFA ⩾ 95° (134 patients) ($p < 0.001$).

ΔPFA ⩾ 95° rates were 95% (57/60) and 27.8% (77/277) in patients with ΔSPT ⩾ 20° and ΔSPT < 20°, respectively (odds ratio [OR] 49.35; CI, 15.01–162.28; $p < 0.001$) (Figure 3) (Table 2).

ΔSPT ⩾ 20° was 42.5% (57/134) and 1.5% (3/203) in patients with or without ΔPFA ⩾ 95°, respectively (OR 49.35; CI, 15.01–162.28; $p < 0.001$) (Figure 4).

Rates of abnormal spinopelvic mobility associated with spinopelvic parameters regarding ΔPFA are summarised in Table 3.

Discussion

Pelvic femoral angle from a standing to a flexed-seated position

The mean ΔPFA from a standing to a seated position was 87.9°, and it was higher in men than in women. Although this mean mobility was lower than that of a recent study, we analysed an older population with hip arthritis.[21] Ageing reduces the mobility of the hip, as does arthritis, and it correlates with loss of femoral head contour, cam deformity, acetabular bone loss and decreased joint space.[22] Hypermobility of the hip may be constitutional, especially in patients with low lumbar lordosis, who are identified as "hip users";[23] it can also be due to a compensation mechanism of sagittal spinal disorder or reduction in LL when ageing is accompanied by an upright posture in which relatively greater hip flexion is needed to achieve a balanced position.[21]

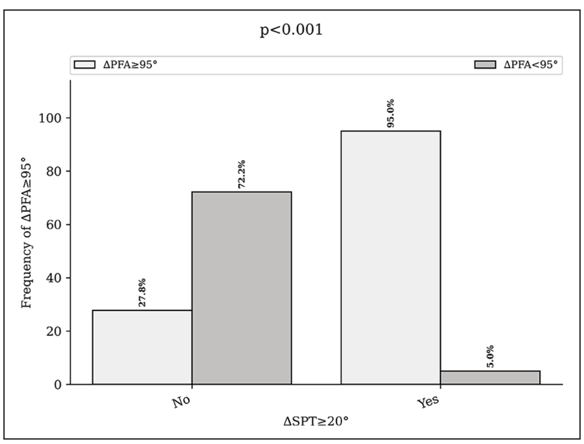

Figure 3. Frequency of ΔPFA ⩾ 95° according to the presence of abnormal spinopelvic mobility. This figure shows the frequency of high hip mobility (ΔPFA ⩾ 95°) from the standing to sitting position in patients with or without abnormal spinopelvic mobility (ΔSPT ⩾ 20°).
SPT, spinopelvic tilt; PFA, pelvic femoral angle.

Using the Youden index enabled selection of an optimal threshold value for ΔPFA at 95° regarding abnormal spinopelvic mobility. A lower flexion in the arthritic hip is responsible for a posterior spinopelvic tilt in the seated position, which is probably compensative of lumbar flexion to maintain an upright position. When moving to the flexed seated position, decreased flexion of the arthritic hip prevents the pelvis from tilting anteriorly.[24] This cutoff point showed good sensitivity at 91.7% and a very good negative predictive value, with only 5% of patients with ΔSPT ⩾ 20° having ΔPFA < 95°. Furthermore, studies described higher mobility of the hip as a risk factor for anterior impingement and concluding that the hip accounts for ¾ of the standing-to-sitting movement, but with great variation.[25] Nevertheless, high mobility of the hip alone is not sufficient to predict the risk of adverse spinopelvic mobility, with only 40% if greater than 95°. This high mobility of the hip defined by ΔPFA ⩾ 95° in a flexed seated position differs from the classical definition of hypermobility at 75° defined by Tezuka et al.[15] but was analysed in a relaxed seated position. Some authors measure PFA in both seated positions, and the average difference between the 2 positions is approximately 20°,[21,26] which can explain the threshold found in the present study.

Evaluation of spinopelvic parameters and relation between ΔSPT and ΔPFA

Although some spinopelvic parameters have been identified as risk factors for adverse spinopelvic mobility,[13] the association with PFA analysis demonstrates increased sensitivity. Excessive posterior spinopelvic tilt in a standing

Table 2. Contingency table of adverse spinopelvic mobility according to hip mobility and background.

Overall population	ΔSPT < 20°	ΔSPT ⩾ 20°	
n = 337	*n* = 277	*n* = 60	
ΔPFA < 95°, *n* = 203	200 (59.3%)	**3 (0.9%)**	
ΔPFA ⩾ 95°, *n* = 134	77 (22.8%)	**57 (16.9%)**	
Background			***p*-value**
Age years, mean (range)	63 (24/80)	68 (32/82)	**<0.001**
SPT, mean (range)	1.1° (−22°/23°)	−5.3° (−31°/14°)	**<0.001**
Lumbar flexion, mean (range)	51.8° (17°/92°)	45.3° (15°–70°)	**<0.001**
Lumbar lordosis, mean (range)	58.9° (22°/88°)	55.8° (28°/93°)	0.073
Pelvic incidence, mean (range)	55.4° (28°/90°)	54.7° (24°/99°)	0.714
PI-LL, mean (range)	−3° (−39°/35°)	−1.3° (−33°/29°)	0.318
ΔPFA, mean (range)	83° (2°/134°)	110.4° (63°/139°)	**<0.001**

SPT, spinopelvic tilt, PFA, pelvic femoral angle; LL, lumbar lordosis; PI, pelvic incidence.
Values in bold indicate statistical significance.

position, as measured by SPT ⩽ −10°, showed a rate of ΔSPT ⩾ 20° for 40% of the patients to 70% with ΔPFA ⩾ 95°, PI-LL mismatch ⩾10° for 22% to 44% and for 43% to 60% in patients with a stiff spine. In contrast, patients without high mobility of the hip, representing 60%, had a very low risk (1.5%) of abnormal spinopelvic mobility regardless of spinopelvic risk factors. However, the difference was not statistically significant when analysing lumbar flexion ⩽20° due to the small number of patients. This group comprised only 2% of the population (7 patients) matched with the literature.[12] It seems also that despite a strong relationship with abnormal spinopelvic mobility, these limits might be too restrictive to identify 17.8% of patients with ΔSPT ⩾ 20°.

If an increase in hip flexion can be a compensatory mechanism for sagittal imbalance or lumbar stiffness ("hip users"),[4] hip stiffness due to osteoarthritis appears to limit this mechanism, and hip flexion becomes a necessary condition for adverse pelvic mobility.

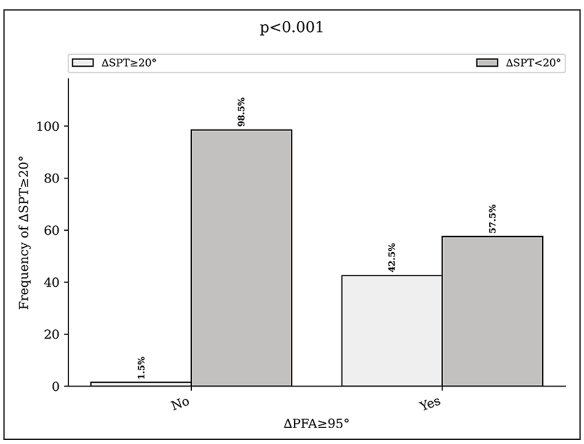

Figure 4. Frequency of abnormal spinopelvic mobility according to the presence of ΔPFA ⩾ 95°. This figure shows the frequency of abnormal spinopelvic mobility (ΔSPT ⩾ 20°) from the standing to sitting position in patients with or without high hip mobility
SPT, spinopelvic tilt; PFA, pelvic femoral angle.

Strengths and limitations

Studies have shown restoration of hip flexion after hip replacement,[20,27] and an increase in sacral slope when seated correlated with the prior stiffness of the hip.[24,28–30] Patients with hip arthritis can have a stiff hip, and a strong relationship has been shown between the change in ΔPFA and ΔSS between preoperative and postoperative values from the standing to flexed seated position.[26] Some authors found in some patients undergoing THA that pelvic axial rotation may be 'hip-driven,' and may be expected to change after THA.[28] The presence of risk factors for adverse spinopelvic mobility has demonstrated these as a factor in the risk of postoperative dislocation,[11,12,16,17] particularly in lumbar fusions,[31,32] and some authors recommend the use of a dual-mobility cup in these patients.[31,33,34] An increase in spinopelvic motion and decreased hip motion preoperatively are associated with the postoperative radiographic changes related to increased dislocation risk.[35] It underscores the necessity to assess patients with prior stiffness of the hip (ΔPFA < 95°) associated with spinopelvic risk factors, that could reveal abnormal spinopelvic mobility after the restoration of femoral flexion with THA and possibly an anticipation in the orientation of implants or the use of a dual-mobility cup. Further studies are needed to analyse the change in FPA in patients with sagittal spinal disorder and the consequence in terms of abnormal spinopelvic mobility, including the surgical technique, limb lengthening and postoperative care, which can have influences.

The present study has certain limitations. First, we retrospectively analysed a consecutive cohort. A prospective study remains desirable. In this consecutive retrospective series, we did not analyse the stiffening of the contralateral hip, which has an impact on preoperative pelvic mobility. This variable appears to be important in anticipating postoperative pelvic mobility changes.[30,35] The quality of the radiographs being assessed is important for analysing PFA, and 10 patients were excluded because of lack of quality; radiology technicians also need special training on proper patient positioning. Poor radiograph quality may

Table 3. Spinopelvic parameters and risk of adverse spinopelvic mobility and impingement according to hip mobility.

Spinopelvic parameters	Overall population	ΔPFA < 95°	ΔPFA ⩾ 95°	*p*-Value
	n = 337	*n* = 203	*n* = 134	
	Rate of ΔSPT ⩾ 20°			
Overall population	17.8% (60/337)	1.5% (3/203)	42.5% (57/134)	<**0.0001**
Spinopelvic parameters				
SPT ⩽ −10°	41.8% (18/43)	0% (0/17)	69.2% (18/26)	<**0.0001**
Lumbar flexion ⩽ 20°	42.8% (3/7)	0% (0/2)	60% (3/5)	0.42
PI-LL ⩾ 10°	22.6% (12/53)	0% (0/26)	44.4% (12/27)	**0.0002**

SPT, spinopelvic tilt; PI, pelvic incidence; LL, lumbar lordosis; PFA, pelvic femoral angle.
Values in bold indicate statistical significance.

affect interobserver reliability,[36] but we found a very good ICC when comparing resident with experienced surgeons, corresponding to previous studies (ICC 0.91).[36] This measurement can be easily performed in daily practice and requires only 2 lateral x-rays. Moreover, the risk of dislocation was not analysed in this study but only the rate of abnormal spinopelvic mobility. Combined anteversion, implant positions, offset and leg length are important to analyse risk of dislocation and should be anticipated before surgery.[17,37–39]

In conclusion, in addition to being a risk factor for impingement, high flexion of the hip ($\Delta PFA \geqslant 95°$) seems to be a necessary condition for abnormal spinopelvic mobility. A preoperative analysis of patients with lower hip mobility, associated with pejorative spinopelvic risk factors, might identify patients with abnormal spinopelvic mobility after the restoration of femoral flexion.

Declaration of conflicting interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article:
TA: is a consultant for: Corin, Lape Medical.
LL: is a consultant for: Amplitude, Corin, Lape Medical.
GR: is a consultant for: Euros, Medtronic's.
All other authors declare that there is no conflict of interest.

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