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Original Research

The Prevalence of Abnormal Spinopelvic Relationships in Patients Presenting for Primary Total Hip Arthroplasty

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ABSTRACT

Background: The prevalence of an abnormal spinopelvic relationship in patients presenting for primary total hip arthroplasty (THA) is not well known. The purpose of this study was to identify the prevalence of abnormal spinopelvic relationships in patients presenting for primary THA.

Methods: A retrospective chart review of 338 consecutive, nonselected patients undergoing primary THA from the practice of 2 fellowship-trained adult reconstruction surgeons was performed (J.E.O. and T.S.B.). Sitting and standing radiographs were measured for lumbar lordosis (LL), pelvic incidence (PI), sacral slope (SS_{stand}), and pelvic tilt; the sacral slope was also measured on sitting radiographs (SS_{sit}). Patients were assessed for the presence of spinopelvic imbalance, defined as PI−LL>10°, and decreased spinopelvic motion, defined as $SS_{stand}-SS_{sit}< 10°$. Descriptive statistics were reported.

Results: A cohort of 338 patients was identified; 110 were excluded. In total, 228 unique patients underwent measurement. One hundred one of 228 patients (44.3%) in the cohort were female. The mean age of the cohort was 60.0 ± 13 years, with the mean body mass index of 31 ± 7 mg/kg^2. Spinopelvic imbalance (PI−LL > 10°) was present in 142 of 228 patients (62.3%). Decreased motion at the spinopelvic junction ($SS_{stand}-SS_{sit} < 10°$) was present in 78 of 228 patients (34.2%). Fifty (21.9%) patients had both spinopelvic imbalance and decreased spinopelvic motion.

Conclusions: In a cohort of 228 patients presenting for primary THA, the prevalence of spinopelvic imbalance was 62.3%, the prevalence of decreased spinopelvic motion was 34.2%, and the prevalence of both spinopelvic imbalance and decreased spinopelvic motion was 22%. Hip surgeons are likely to encounter patients with abnormal spinopelvic relationships.

Introduction

Patients with abnormal spinopelvic mobility undergoing total hip arthroplasty (THA) are at a higher risk of postoperative complications, including dislocation [1-7]. Multiple studies have attempted to classify these abnormal spinopelvic relationships based on sagittal balance and the degree of stiffness in the lumbosacral spine [6-9]. Although there are slight differences between these classifications, there is agreement as to which pattern has the highest risk of dislocation: a flatback or kyphotic deformity of the lumbar spine with decreased spinopelvic motion [2,3,6-9]. However, the prevalence of flatback spinal deformity and decreased spinopelvic motion in patients presenting for primary THA is not well known [6-9]. A better understanding of the prevalence of abnormal spinopelvic relationships in patients indicated primary THA is needed before specific solutions (ie, dual-mobility implants) can be routinely used.

The purpose of this study was to identify the prevalence of patients with spinopelvic imbalance and/or decreased spinopelvic motion indicated for primary THA based on published definitions for these parameters. We hypothesized the following: the prevalence of spinopelvic imbalance would be <20%, the prevalence of decreased spinopelvic motion would be <20%, and the prevalence

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of patients with spinopelvic imbalance and decreased spinopelvic motion would be <10%.

Material and methods

This study was granted approval by our institutional review board. A retrospective chart review of consecutive patients undergoing primary THA from October 1, 2017, to December 31, 2018, from the practice of 2 fellowship-trained adult reconstruction surgeons (J.E.O. and T.S.B.) was performed. Patients were identified using Current Procedural Terminology code 27130. Inclusion criteria were as follows: age ≥18 years, undergoing primary THA, with preoperative standing and sitting radiographs that included lumbar vertebrae 1-5, the sacrum, and the femoral heads. Exclusion criteria were as follows: patients aged <18 years or patients with inadequate imaging (no sitting or standing radiographs, sitting or standing radiographs that failed to include all lumbar vertebrae, the sacrum, or femoral heads). If patients had both hips replaced during the study period, they were only counted once in the cohort and images before their first THA were evaluated. In total, 338 patients were eligible for inclusion. One hundred ten patients were excluded (3 with inadequate follow-up and 107 with inadequate imaging), leaving 228 patients remaining in the final cohort. All 107 patients with inadequate imaging had inadequate imaging for the same reason: the radiograph was truncated proximally such that we could not see the cephalad endplate of the L1 vertebrae and therefore could not measure the lumbar lordosis (LL) in accordance with our established protocol. Patient demographics (age, sex, body mass index [BMI]) and information on preoperative diagnosis, a history of posterior spinal fusion (PSF), levels of PSF, and inclusion of the sacrum in the PSF construct were collected from the electronic medical record.

Radiographic definitions and measurement protocols

Sitting and standing radiographs were taken in accordance with an established protocol for patient positioning and imaging technique. The current protocol for preoperative imaging of all the hip arthroplasty surgeons at our institution includes sitting and standing lateral EOS (EOS Imaging, Paris, France) radiographs of the lumbar spine and pelvis including lumbar vertebrae 1-5, the sacrum, and the femoral heads, as well as anteroposterior and lateral views of the pelvis and affected hip. Measurements were performed independently by 2 separate observers (C.N.C. and M.S.W.). Measurements were performed digitally on lateral EOS standing and sitting preoperative radiographs using the CARESTREAM Vue Motion imaging system (Carestream Health; Rochester, NY). Standing radiographs were measured for the LL, pelvic incidence (PI), sacral slope (SS_{stand}), and pelvic tilt (PT). The SS was also measured on sitting radiographs (SS_{sit}). The LL was measured using Cobb angles with lines subtended across the cephalad endplate of L1 and the caudal endplate of L5 (Fig. 1). The PI, PT, and SS were measured in accordance with the methods presented by Duval-Beaupere et al [10] and Legaye et al [11] (Fig. 1). Each unique measurement was performed twice by each observer; the average of those measurements was recorded and used for analysis. Each patient was assessed for the presence of spinopelvic imbalance, defined as $PI-LL>10°$ as per published standards [8,9,12]. Patients were also assessed for the presence of decreased spinopelvic motion, defined as a difference between standing and sitting values in SS of <10° ($SS_{stand}-SS_{sit} < 10°$) based on previously published criteria [8,9].

Patient cohort

In total, 228 unique patients were identified and underwent measurement. One hundred one of 228 patients (44.3%) in the cohort were female. The mean age of the cohort was 60.0 ± 13.1 years, with the mean BMI of 31.1 ± 6.87 mg/kg^2. Preoperative diagnoses included primary osteoarthritis (191 patients; 83.8%), avascular necrosis (26 patients; 11.4%), hip dysplasia (9 patients; 3.9%), post-traumatic arthritis (1 patient, 0.4%), and rheumatoid arthritis (1 patient; 0.4%). Nine (3.9%) patients had

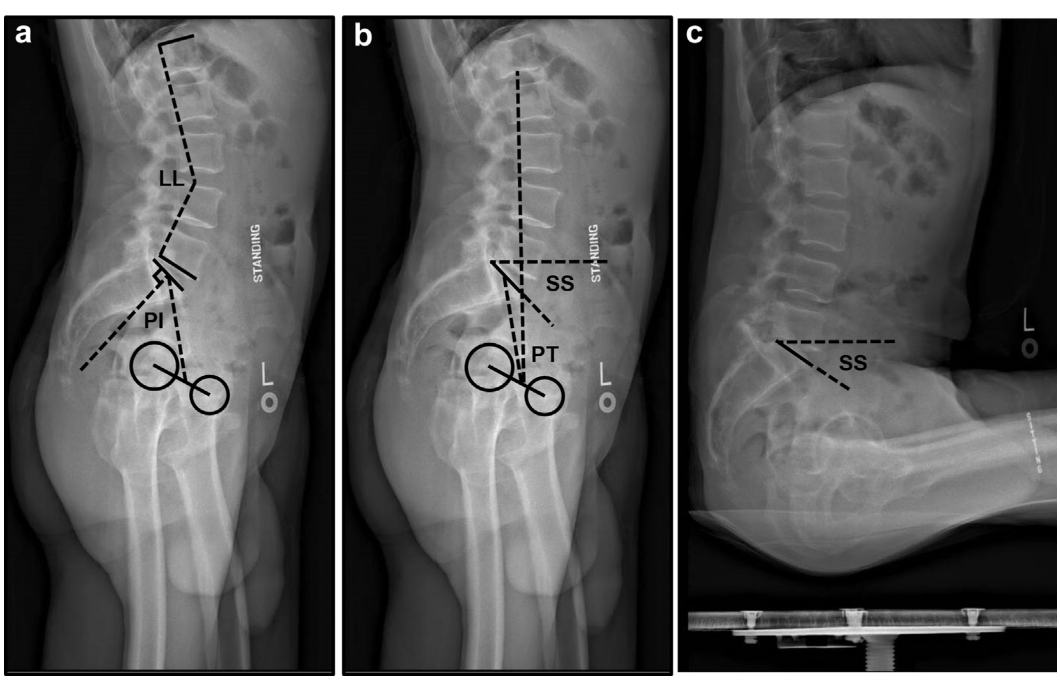

Figure 1. Radiographic measurement protocol. Measurement protocol for preoperative standing radiographs for the following parameters: the lumbar lordosis and pelvic incidence (a), sacral slope and pelvic tilt (b). Measurement protocol for the sacral slope on sitting radiographs is demonstrated in panel (c).

Table 1
Mean values of radiographic measurements on standing and sitting radiographs.

Measurement	Standing	Sitting	ΔStanding to sitting
LL (°; mean ± SD)	43.5 ± 14.7	-	-
PI (°; mean ± SD)	57.6 ± 12.1	-	-
SS (°; mean ± SD)	42.1 ± 11.8	26.5 ± 12.2	15.6 ± 13.1
PT (°; mean ± SD)	15.3 ± 8.8	-	-
PI − LL (°; mean ± SD)	14.1 ± 13.7	-	-

Δ, change; SD, standard deviation.

a prior PSF; 5 of 9 patients had a PSF construct that extended to the sacrum.

Statistical analyses

Descriptive statistics, including prevalence, mean values, and standard deviations for patient demographics and radiographic parameters, were reported. A sample of 20 radiographs was used to calculate intraclass correlation coefficients (ICCs) and their respective 95% confidence intervals (CIs) to measure intraobserver and interobserver reliability for measurements of standing LL, PI, PT, SS_{stand}, and SS_{sit}. Statistical analyses were performed using IBM SPSS Statistics (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.).

Results

The mean values of radiographic measurements are presented in Table 1. Spinopelvic imbalance (PI−LL>10°) was present in 142 of 228 patients (62.3%). Decreased motion at the spinopelvic junction (SS_{stand}−SS_{sit}< 10°) was present in 78 of 228 patients (34.2%). Fifty patients (21.9%) had both spinopelvic imbalance and decreased spinopelvic motion.

Intraobserver ICC values and their respective 95% CI for each measurement were as follows: LL, 0.96 (95% CI, 0.90-0.98); PI, 0.88 (95% CI, 0.71-0.95); PT, 0.95 (95% CI, 0.88-0.98); SS_{stand}, 0.87 (95% CI, 0.71-0.95); and SS_{sit}, 0.70 (95% CI, 0.90-0.98). Interobserver ICC values and their respective 95% CI for each measurement were as follows: LL, 0.64 (95% CI, 0.28-0.84); PI, 0.67 (95% CI, 0.33-0.85); PT, 0.66 (95% CI, 0.30-0.85); SS_{stand}, 0.86 (95% CI, 0.69-0.94); and SS_{sit}, 0.87 (95% CI, 0.76-0.96).

Discussion

Abnormal spinopelvic relationships are becoming increasingly recognized as a potential source of instability after primary THA [1-3,5-9,13]. Patients with spinopelvic imbalance and decreased motion at the spinopelvic junction who undergo primary THA are thought to be among those at the highest risk for dislocation postoperatively [2,6-9,14]. In a study of 1000 primary THAs, Esposito et al. [3] identified 12 patients who had a dislocation, 11 of whom (91.7%) had multilevel degenerative changes in the lumbar spine or a history of a prior PSF. Heckmann et al. [5] reviewed a cohort of 20 patients from their practice with late dislocations (>1 year) after primary THA; there were 9 anterior and 11 posterior dislocations. Eight of 9 (88.9%) patients who had anterior dislocations and 10 of 11 (90.9%) patients who had posterior dislocations had abnormal spinopelvic dynamics, with the direction of dislocation being directly related to the combined sagittal index—a measure of motion of the lumbar spine, pelvis, and femur when transitioning from sitting to standing [5]. To minimize the risk of THA dislocation in patients with abnormal spinopelvic relationships, several potential solutions have been proposed: undergo PSF before primary THA to restore sagittal plane balance (and therefore baseline acetabular orientation) [7,9,15], the use of computer navigation to obtain unique and specific acetabular versions based on the patient's individual spinopelvic parameters, and the use of dual mobility (DM) prostheses [6-9,14,16,17]. In a 2017 study, Stefl et al. [7] evaluated a cohort of 160 hips before and after primary THA. All patients in the cohort underwent surgery performed by a single surgeon who used computer navigation for acetabular component positioning [7]. Preoperatively, the authors identified 42 of 160 (26.2%) hips with spinopelvic imbalance; postoperatively, 33 of 42

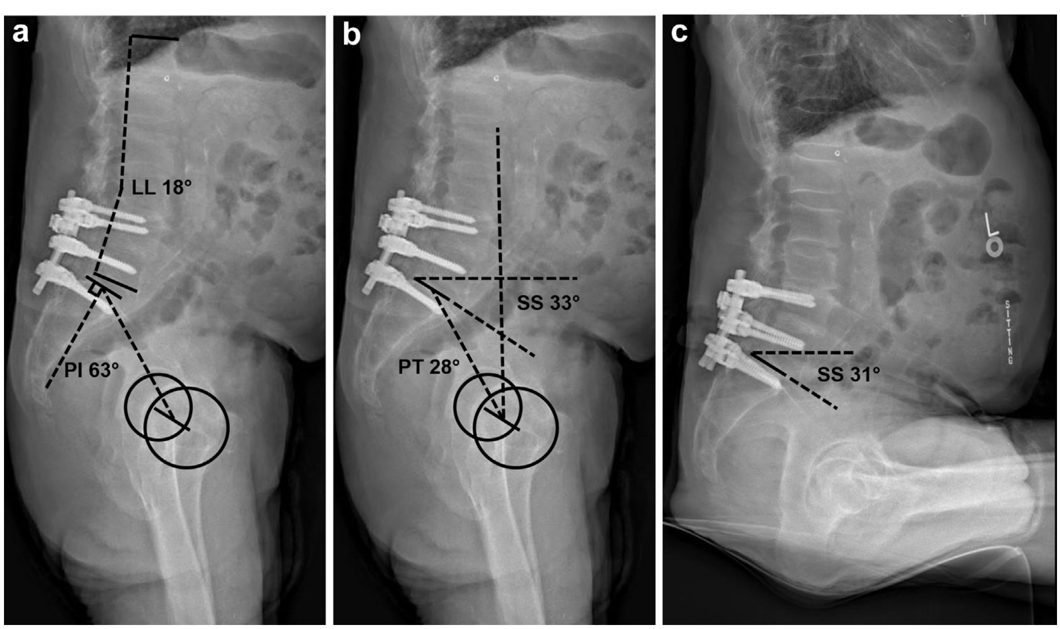

Figure 2. Radiographic measurements in a patient with spinopelvic imbalance and decreased spinopelvic motion. Standing radiographs (A, B) of a 69-year-old man with a previous L4-S1 PSF. Note the relatively small amount of lumbar lordosis, as well as the discordance between the lumbar lordosis and pelvic incidence, indicative of spinopelvic imbalance. Sitting radiograph (C) of the same patient. Note the relatively small amount of change in the sacral slope between standing and sitting radiographs, indicative of decreased spinopelvic motion.

(78.6%) hips had normal acetabular ante-inclination and sacral acetabular angles [7]. Seven patients continued to have decreased spinopelvic motion after surgery, leaving them at a high risk for impingement; the authors considered these patients to be candidates for DM prostheses [7]. The authors concluded that precise placement of the acetabular component in the correct inclination and anteversion (based on the patient's individual spinopelvic parameters) could compensate for a patient's spinopelvic imbalance in most cases [7].

Currently, data surrounding the use of DM prostheses specifically in patients with abnormal spinopelvic relationships are somewhat limited. However, in a cohort of 116 patients, Dagneaux et al. [14] identified lower rates of dislocation in a DM prosthesis cohort relative to a traditional implant cohort despite similar acetabular positioning and a relatively equal prevalence of abnormal spinopelvic relationships between cohorts. The authors postulated that DM constructs may be able to provide a protective (ie, minimize the risk of dislocation) benefit to primary THA in patients with severe spinal degeneration [14]. Vermersch et al. [18] evaluated a cohort of 100 patients who underwent primary THA with a dual-mobility construct; patients in this cohort had a mean age of 73 $\pm$ 11 years with a mean BMI of 26 $\pm$ 5 kg/m^2. At 5 years of follow-up (follow-up rate: 86%), implant survivorship was 100%, with no dislocations, prosthetic loosening, or intraprosthetic failures [18]. The prevalence of spinopelvic pathology in this study is unknown but unlikely to be zero, given the mean age of cohort [18]. DM prostheses have been shown to be comparable with conventional prostheses in terms of complications and survivorship in the setting of primary THA in patients who are at "high risk" for dislocation (neuromuscular disorders and history of alcohol abuse) at short- and medium-term follow-ups [16,19,20]. However, DM constructs are not infallible. Although potentially beneficial in primary THA [14,16,17], DM prostheses may be more expensive to implant [21] and have alternative modes of failure relative to traditional THA bearings such as intraprosthetic dislocation. Furthermore, there is the potential for production of metal debris and corrosion if modular DM implants are used, as well as failure at this modular interface [22,23].

Before DM constructs can be recommended for patients with abnormal spinopelvic dynamics, a greater understanding of the prevalence of abnormal spinopelvic dynamics in patients presenting for primary THA is needed. In the present study of 228 patients, the prevalence of spinopelvic imbalance was 62.3% and the prevalence of decreased spinopelvic motion was 34.2% (Fig. 2). Both values were higher than our original hypothesis of a prevalence of <20%. Furthermore, more than 1 in 5 (21.9%) patients indicated for a primary THA had spinopelvic imbalance and decreased spinopelvic motion. Per recent literature, these patients would warrant strong consideration for the use of DM prostheses [6-8,24]. Esposito et al. [13] examined a cohort of 242 patients undergoing primary THA and found the prevalence of multilevel degenerative changes in the lumbar spine to be 39%. In the aforementioned study by Stefl et al. [7], the authors found that approximately 54% of patients presented with normal spinopelvic mobility (87/160 patients) and 26.2% (42/160) presented with dangerous or pathologic spinopelvic mobility [7]. This distribution between normal and abnormal spinopelvic dynamics is similar to the distribution found in the present study.

There are limitations to the present study. First, this is a descriptive study, aimed at determining the prevalence of spinopelvic imbalance and decreased spinopelvic mobility. We did not evaluate any intraoperative factors, including positioning of the acetabular component, the use of DM prostheses, postoperative complications, or the potential effects of preoperative spinopelvic imbalance on these factors. Furthermore, we did not measure the potential change in spinopelvic parameters from preoperatively to postoperatively. Spinopelvic parameters can change after THA secondary to release of contractures about the hip joint [6,25,26]. Second, this study evaluated a study cohort of patients from the Midwestern United States, with potential limitations in generalizability of study findings to cohorts in other regions within the United States or other countries. Third, with the measurement of any subjective radiographic parameter using a digital system, there is at least a small degree of inherent measurement error or variability. This study is based on measurements conducted by 2 independent observers. Although all interobserver reliability ratings in the present study were of moderate to excellent correlation, there is not 100% agreement between measurers, with the potential to influence study results.

Conclusions

Abnormal spinopelvic relationships have been shown to be a significant factor in instability after primary THA. In a cohort of 228 patients presenting for primary THA, the prevalence of spinopelvic imbalance was 62.3%, the prevalence of decreased spinopelvic motion was 34.2%, and the prevalence of both spinopelvic imbalance and decreased spinopelvic motion was 21.9%. Most hip surgeons are highly likely to encounter patients with abnormal spinopelvic relationships and should be aware of techniques to maximize stability in this patient population. There is a need for data demonstrating success of DM articulations in minimizing the risk of dislocation in this patient population, especially given the large number of patients who may be receiving this implant design based on their spinopelvic pathology.

Conflict of interest

Jesse E. Otero, MD, PhD is a board or committee member of the American Association of Hip and Knee Surgeons and is a paid consultant at and receives research support from DePuy, a Johnson & Johnson company. Timothy S. Brown, MD is a board or committee member of the American Association of Hip and Knee Surgeons and also a member of the editorial or governing board of the *American Journal of Orthopedics*.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2020.05.010.

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