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Spinal Factors Influencing Change in Pelvic Sagittal Inclination From Supine Position to Standing Position in Patients Before Total Hip Arthroplasty

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ABSTRACT

In some atypical patients, pelvic sagittal inclination (PSI) changes posteriorly by >10° from supine to standing position before total hip arthroplasty (THA). Several studies have suggested PSI in standing position is related to lumbar degeneration. The purpose of this study was to investigate spinal factors influencing changes in PSI from supine to standing position before THA. Participants comprised 163 consecutive patients who had undergone THA. Presence of compression fractures, presence of lumbar spondylolisthesis, thoracic kyphosis angle, lumbar lordosis angle, S1 anterior tilt angle and T4 plumb line position were investigated as spinal factors. Presence of compression fractures, age, presence of lumbar spondylolisthesis and small S1 anterior tilt angle were independently associated with posterior change in PSI from supine to standing position in patients before THA.

In total hip arthroplasty (THA), cup alignment is one of the most important factors related to impingement, dislocation and wear [1–3]. Cup alignment is affected by the inclination of the pelvis and, in particular, cup anteversion is drastically changed by pelvic sagittal inclination (PSI) when cup orientation is less than 45° [4]. Lembeck et al reported that a 1° decrease in PSI (reclination) resulted in approximately 0.7° of increase in radiographic cup anteversion [4]. Nonetheless, PSI in a supine position has been reported to offer a good reference pelvic position for aiming cup orientation to avoid implant impingement and dislocation [5,6]. PSI does not usually change more than 10° from supine to standing position either preoperatively or after THA [7–9]. However, there are some 'atypical' patients whose PSI changes of >10° posteriorly from supine to standing position [7–9]. In those atypical patients the risk of posterior implant impingement during hip extension and/or external rotation may increase during standing activities when cup is placed by using PSI in supine position as the reference plane.

One study suggested that the anterior pelvic plane (APP) through the most anterior aspect of the pubic tubercle and bilateral anterior superior iliac spines (ASISs) is often tilted posteriorly even when these atypical patients are supine, and that these patients were older than the other "typical" patients whose PSI change from supine to standing position was within 10° [9]. Several studies have also suggested that PSI in standing position is affected by lumbar degeneration such as degenerative disc diseases and degenerative spondylolisthesis [10–12]. But, it has been unclear whether age and spinal degenerative changes are related, dependently or independently, to PSI in standing position or the PSI change from supine to standing position. If we can identify major influencing factors related to large PSI changes from supine to standing position, we may find a prophylactic method for the prevention of large PSI changes from supine to standing position. However, no reports have evaluated factors related to PSI change >10° from supine to standing position in consideration of THA.

The purpose of this study was therefore to investigate spinal factors influencing the PSI change from supine to standing position in patients who underwent THA, using standing lateral radiographs of the whole spine.

Materials and Methods

Participants in this study comprised 163 consecutive patients who underwent primary THA in our hospital between January 2010 and December 2011. Institutional review board approval was obtained for this study. Mean age at the time of THA was 61.8 ± 12.4 years (range, 26 to 86 years). There were no patients with neurologic diseases such as Parkinson's disease, brain infarction, or multiple sclerosis. Antero-posterior (AP) radiographs of the pelvis in standing position were taken preoperatively with the line between bilateral ASISs perpendicular to the central beam of X-ray. The target for the central X-ray was over the superior margin of the pubic symphysis. Standing lateral radiographs of the whole spine were taken preoperatively. Each

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patient was standing in a comfortable posture while the hands were placed on an antero-lateral support bar to avoid overlap of the upper extremities and spine.

Computed tomography (CT) of the pelvis was also performed preoperatively for navigation THA. Preoperative PSI in a supine position was measured on CT using 3D Template software (Kyocera Medical, Osaka, Japan). On multi-planar reconstructions (MPRs), the pelvis was rotated to make the line between bilateral ASISs parallel to the horizontal axis. Digitally reconstructed radiographs (DRRs) of the lateral view of the pelvis were generated and the angle between APP and vertical axis was defined as PSI in the supine position. A positive value for the angle indicated anterior tilting of the pelvis. The ratio of the vertical diameter (A) to the horizontal diameter (B) (VH ratio) of the pelvic foramen on standing radiographs (Fig. 1) was measured to calculate PSI in the standing position. To match the VH ratio on a DRR to that on standing radiographs, the pelvis was sagittally rotated on the lateral MPR and the sagittal inclination of APP represented PSI in the standing position (Fig. 1). In some patients with sagittal inclination of APP in the standing position tilted strongly posteriorly, the pelvic foramen was not identifiable on standing radiographs. In those cases, VH ratio of the right obturator foramen was used to calculate PSI in the standing position. Some authors measured PSIs on lateral radiographs [13–15]. However, soft tissue noise can make landmark localization difficult and failure to observe landmarks could introduce large errors of measurement [13]. The technique of matching the CT images and radiographs used in this study has often been used to measure PSI in standing position [7–9,16,17]; a high degree of PSI measurement accuracy using this method has been reported [7].

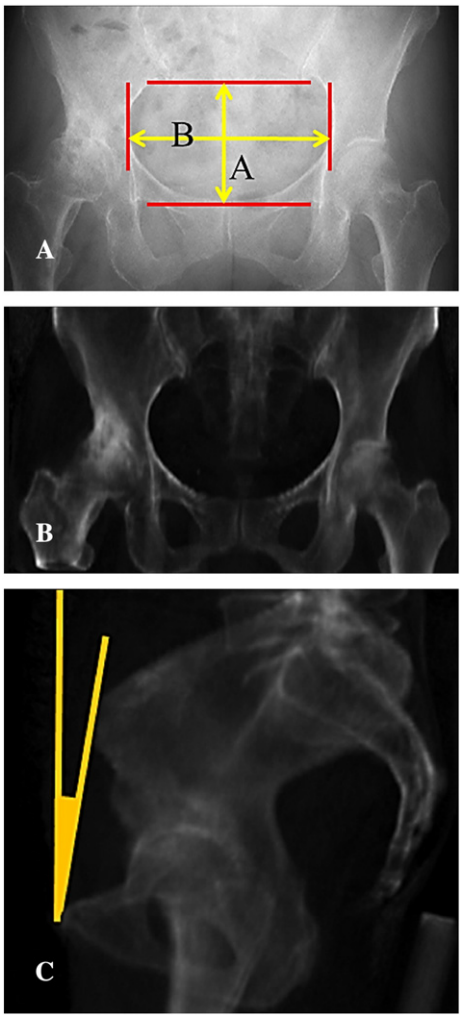

Fig. 1. Measurement of PSI in a standing position. (A) On AP radiographs of the pelvis in a standing position, vertical diameter of the pelvic foramen (A) divided by horizontal diameter of the pelvic foramen (B) was calculated as VH ratio. (B) The pelvis was rotated sagittally until VH ratio of the pelvic foramen on DRR became similar to that of standing AP radiographs. (C) On sagittal DRR, the angle between APP and the vertical axis was measured as PSI in a standing position.

When the PSI change from supine to standing position was >10° posteriorly, the patient was classified as showing atypical posterior pelvic tilt on standing (Group P). The remaining patients were classified as the control group (Group C). In all 163 patients, mean change of PSI from supine to standing position was −6.9 ± 5.7° (range, −25.3° to 8.6°). Forty-one patients (25%) were in Group P and 122 patients (75%) were in Group C.

On standing lateral radiographs of the whole spine, presence of compression fracture and lumbar spondylolisthesis was evaluated. Presence of compression fracture was defined when wedge, biconcave, or compression deformities as described by Eastell et al were present [18]. Presence of lumbar spondylolisthesis was diagnosed when a lumbar vertebra showed >10% of anterior translation compared to the adjacent lower vertebra. The following radiographic parameters were also measured: thoracic kyphosis angle, defined as the angle between lines drawn along the inferior endplate of the T12 vertebrae and the superior endplate of T4; lumbar lordosis angle, defined as the angle between lines drawn along the superior endplate of S1 and the superior endplate of L1; S1 anterior tilt angle, defined as the angle between a line along the superior endplate of S1 and the horizontal line; and T4 plumb line position, defined as the distance between the anterior tip of the superior endplate of S1 and the plumb line through the centroid of T4 (positive value indicates the T4 plumb line was located anterior to the anterior tip of S1). Although the C7 plumb line is often used as a parameter of sagittal spinal balance in the literature [19,20], the T4 plumb line was used in this study because of the unclear contour of the C7 vertebra on lateral radiographs of the whole spine.

Parameters including age, PSI in supine position, thoracic kyphosis angle, S1 anterior tilt and T4 plumb line were compared between Groups P and C by non-parametric Mann–Whitney U test. Parameters including gender, presence of compression fracture and presence of lumbar spondylolisthesis were compared between Groups P and C using Fisher's exact test. Hip diagnosis was compared between Groups P and C using the chi-square test.

Multiple regression analyses were performed to compare the relationship between degree of change in PSI from supine to standing position and all the above parameters. Values of $P < 0.05$ were considered to indicate statistical significance. Statistical analyses were performed using SPSS version 19 software (SPSS, Chicago, IL, USA).

Results

The characteristics of patients in Groups P and C are shown in Table 1. Significant differences between Groups P and C were evident in age, PSI in supine position, presence of compression fracture, presence of lumbar spondylolisthesis, lumbar lordosis angle, S1 anterior tilt angle and T4 plumb line position.

In multiple linear regression analysis, the parameters that independently influenced the change in PSI from supine to standing position were presence of compression fracture (standard partial regression coefficient (β) = −0.20, $P = 0.005$), age ($\beta = -0.15$, $P = 0.038$), presence of lumbar spondylolisthesis ($\beta = -0.15$, $P = 0.033$) and S1 anterior tilt angle ($\beta = 0.34$, $P < 0.001$) (Table 2). The multiple correlation coefficient (r) was 0.543.

Discussion

This study is the first to report relationships between spinal radiographic parameters and the change in PSI from supine to standing position. The parameters that multiple linear regression