Positional And Chronological Change In Pelvic Tilt 5 Years After Total Hip Arthroplasty ~ A Three-dimensional Analysis ~

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Introduction: The orientation of the acetabular cup in total hip arthroplasty (THA) is important for achieving satisfactory postoperative outcomes. Precise positioning of the acetabular cup is essential for preventing postoperative complications such as polyethylene wear, implant failure, and dislocation. Pelvic tilt is believed to affect the orientation of the cup; it is thus clinically important to understand changes in pelvic tilt that can occur after THA. When planning THA, it is common to use preoperative pelvic tilt in the supine position (PTsupine) as the functional pelvic plane (FPP) in many cases. Generally, the pelvis tilts to the posterior from the supine position to the standing position, and after THA. The purpose of this study was to investigate positional and chronological change in pelvic tilt 5 years after THA, using a three-dimensional computed tomography (CT) model. And we also examined preoperative factors that affect the pelvic tilt after THA.

Methods: The subjects of this study were 86 patients (86 hips) who underwent THA in our institution, and whom we were able to follow up until 5 years after THA. The patients consisted of 65 females and 21 males, with a mean age of 64.3 years (range: 44~82 years) at surgery. Antero-posterior (AP) radiographs of the pelvis were taken in the supine and standing positions preoperatively and every year after THA. CT images of the pelvis were obtained at 1 week after THA. In order to match the three-dimensional CT models with the AP radiographs of the pelvis, we measured two parameters in the supine and standing AP radiographs (Figure 1): one (Distance A) was the distance between the line connecting the inferior margins of the bilateral sacroiliac joints and the superior margin of the pubic symphysis; the other (Diameter B) was the maximum horizontal diameter of the pelvic foramen. Distance A was then divided by Diameter B to give the A/B Ratio. The three-dimensional CT model was rotated around the horizontal axis until its A/B Ratio matched that of the AP radiograph 1). The pelvic tilt was defined as the angle between the anterior pelvic plane (APP) and the vertical plane. APP was defined as the plane of the bilateral superior anterior iliac spines and the superior margin of the pubic symphysis. Anterior orientation of APP was defined as flexion (positive angle), and posterior orientation was defined as extension (negative angle).

We examined positional change (PC) in pelvic tilt from the preoperative supine position to the standing position 5 years after THA. The patients were divided into three groups on the basis of a 10° change in PC. PC were >-10° but ≤0° in Group A, >-20° but ≤-10° in Group B, ≤-20°in Group C.

To investigate sagittal spino-pelvic alignment, sagittal standing radiographs of the whole spine were also taken preoperatively and 1 year after THA in all patients. We measured sagittal balance (SB, distance between C7 plumb line and hip axis), thoracic kyphosis (TKA, Th1 upper end plate [UEP] - Th12 lower end plate [LEP]) and lumbar lordosis (LLA, Th12 LEP - S1UEP).
For statistical analysis among the three groups, a Mann-Whitney U test was used, and p-values of less than 0.05 were considered significant with a 95% confidence interval. Data are expressed as the mean ± standard deviation.

**Results:** The mean PTsupine of all patients was 2.3° ± 10.4° preoperatively, and -0.9° ± 9.6° at 5 years after THA. The mean pelvic tilt in the standing position (PTstand) of all patients was -2.1° ± 11.7° preoperatively, and -7.3° ± 12.1° at 5 years after THA (Table 1). The mean PC of all patients was -9.6° ± 6.2°, and none showed plus value in PC. Group A consisted of 49 patients (57%) (36 women and 13 men, with a mean age of 63.6 years at surgery); the mean PC was -5.2° ± 0.5°. Group B consisted of 31 patients (36%) (23 women and 8 men, with a mean age of 63.7 years at surgery); the mean PC was -13.7° ± 3.2°. Group C consisted of 6 females (7%) with a mean age of 73.7 years at surgery; the mean PC was -23.2° ± 2.1°, and the maximum PC was 25° to the posterior. The mean PTsupine in group C was -2.5° ± 10.9° preoperatively, and -9.0° ± 8.8° at 5 years after THA. The mean PTstand of all patients was -11.0° ± 15.9° preoperatively, and -26.0° ± 10.6° at 5 years after THA. All patients in group C exhibited posterior change in PTstand at 1 year after THA, and the change continued until 5 years after THA (Figure 2).

In group C, the mean age was significantly older (p=0.028), and the mean preoperative LLA was significantly smaller than the other group (p=0.02).

**Discussion:** With extension of the pelvis after THA, anteversion and inclination of the acetabular component tend to increase. Babisch et al. reported that the cup inclination changes about 0.3° and the cup anteversion changes about 0.8° per 1° change in pelvic tilt 2). Therefore it is clinically important to understand the changes in pelvic tilt that can occur after THA and to determine the types of patients that will be more likely to show greater change in pelvic tilt after THA. Nishihara et al. described that it is reasonable to regard the PTsupine as the FPP and proper pelvic reference frame in determining optimal orientation of the acetabular component in 90% of cases before and 1 year after THA. But they also mentioned that an adjustment of orientation of the acetabular component was needed for the remaining 10% of cases because of change in pelvic tilt 1). In the present study, in 93% of all patients (group A & B) their change in pelvic tilt was less than 20°. But 7% of all patients (group C) showed greater than 20° change in PC to the posterior, and the maximum change in PC was 25° to the posterior. In such a case, according to the report of Babish et al., changes of cup orientation were about 8° increase in cup inclination and about 20° increase in cup anteversion 2). In group C, the mean age was significantly older, and preoperative LLA was smaller than the other group. Their preoperative LLA (mean: 29.8°) was smaller than healthy volunteers’ LLA (35.4°~90.4°). And PTstand in group C tended to shift to the posterior yearly until 5 years after THA.

In old patients with preoperative severe small LLA due to, for example, lumbar compression fracture, it is likely that pelvic tilt will change to the posterior after THA. For these patients, it is important to pay attention to the condition of the spine to avoid further posterior change in pelvic tilt after THA. And cup anteversion should be reduced by several degrees in order to compensate for posterior change in pelvic tilt after THA. However, further studies are necessary to draw more general conclusions for patients outside of this study group, and operative decisions must be individualized. Thus, a greater understanding of postoperative changes in pelvic tilt may improve the outcomes of THA patients.
Significance: Patients whose positional change in pelvic tilt from the preoperative supine position to the standing position 5 years after THA was greater than 20° was older and had smaller LLA. For these patients, spinal care and careful preoperative planning should be needed.

Figure 1. Method of measuring pelvic tilt in three-dimensional CT model
a) AP radiograph of the pelvis
b) Three-dimensional CT model: The three-dimensional CT model was rotated around the horizontal axis until its A/B ratio matched that of the AP radiograph.
c) Pelvic tilt: the angle between APP and the vertical plane (°)

Table 1. Data for all groups  *p<0.05, **p<0.01, ***p<0.005

<table>
<thead>
<tr>
<th>Group</th>
<th>n (Excluded)</th>
<th>Mean age (years)</th>
<th>Pelvic tilt (°) (super/standing)</th>
<th>Spinal data (before THA/year after THA)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Before THA</td>
<td>1Y</td>
</tr>
<tr>
<td>A</td>
<td>40 (17)</td>
<td>63.6 ± 8.2</td>
<td>19.0 ± 9.4</td>
<td>-18.5 ± 3.3</td>
</tr>
<tr>
<td>B</td>
<td>31 (238)</td>
<td>65.7 ± 10.0</td>
<td>-9.7 ± 12.8</td>
<td>-4.9 ± 13.8</td>
</tr>
<tr>
<td>C</td>
<td>9 (209)</td>
<td>73.7 ± 4.7*</td>
<td>-25.3 ± 10.1</td>
<td>-10.2 ± 15.6</td>
</tr>
<tr>
<td>Overall</td>
<td>86 (851)</td>
<td>94.9 ± 8.0</td>
<td>23.7 ± 10.4</td>
<td>-21.6 ± 15.7</td>
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</tbody>
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Figure 2. Change in pelvic tilt in all THA cases  *p<0.05, **p<0.01, ***p<0.005