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ORIGINAL STUDY

Is the pelvis stable during supine total hip arthroplasty?

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Intra- operative changes in pelvic position during total hip arthroplasty (THA) can affect acetabular orientation. We evaluated these changes during supine THA using a proprietary mobile application called PelvicTracker. Twenty- two patients undergoing THA using direct anterior approach were included in the study. In the sagittal plane, the pelvis was extended (anterior tilt) as compared to the start of surgery in 19/ 22 hips at the time of cup implantation (mean extension: 3.1°; range: 1°-6°). In the transverse plane, the pelvis was rolled to the opposite side of surgery in 12 hips (mean roll: 2.8°; range: 1°-5°), to the same side in 8 hips (mean roll: 3.9°, range: 1°-9°) and unchanged in 2 hips at the time of cup implantation. Predicted change in cup version of ≥5° due to changes in pelvic position was seen in 7/22 (32%) patients. Although minor, changes in pelvic position do occur during supine THA which may affect acetabular orientation.

Keywords : direct anterior approach ; total hip arthroplasty ; supine ; pelvic stability ; acetabular component orientation.

INTRODUCTION

The acetabular component orientation after total hip arthroplasty (THA) influences dislocation rates (*5*), wear, (*8*) impingement (*6*) and range of motion (ROM) (*10*). During non- navigated THA, acetabular cup orientation during insertion is often based on the relationship between the operating table and position of the patient. Commonly, it is presumed that the position of the pelvis at the time of cup implantation is the same as it was at the beginning of surgery. And, the surgeon uses this pelvic position as reference in order to obtain desired acetabular component orientation. Studies have shown that the pelvis moves from its original position during surgery and this, accounts for variation in the acetabular component orientation (*2,3,9*). These authors evaluated changes in pelvic position during THA in lateral position (*2,3,9*). In a recent study, Eilander et al reported that supine THA creates a stable pelvic position and provides reliable freehand acetabular component placement (*1*). However, we did not find any report evaluating intra- operative changes in pelvic position during supineTHA, and this was the aim of our study. We developed a proprietary mobile application, PelvicTracker that allowed us to track the movement of the pelvis during supine THA in order to realize

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our aim. We hypothesized that the pelvic position at the time of cup implantation would be the same as its position at the beginning of surgery due to the stability created by supine position.

MATERIALS AND METHODS

Twenty two patients undergoing unilateral THA using direct anterior approach (DAA) between January 2014 and February 2015 were included in this prospective observational study. Indication for surgery was primary osteoarthritis in all cases. The patients were not consecutive, but rather random. Approval from the hospital ethics committee and consent from all the patients were obtained to record and analyse data for research purposes.

Surgical technique

The surgery was performed in supine position without traction table. We used Orthomap v 1.4 (Stryker Leibinger, Freiberg, Germany) navigation system in order to obtain desired cup orientation and restore offset & length in all cases. The navigation tracker was mounted on the contralateral iliac crest using two schanz pins that were inserted an inch proximal to the anterior superior iliac spine (ASIS). We chose the functional pelvic plane (FPP) that accounts for patient's pelvic tilt as reference for cup insertion. The FPP co-ordinates were determined by the navigation system using two anterior superior iliac spines (ASIS) and the operating table plane. The operating table plane reference was obtained by moving the table down and up. An iPhone® 5 with the PelvicTracker application was placed in a sterile transparent plastic cover and mounted on the same clamp as the navigation tracker. It was placed parallel to the transverse axis and perpendicular to the long axis of the body (Figure 1). PelvicTracker is a proprietary mobile application developed by the senior surgeon in liaison with a software developer for iPhone® 5 based on its tri- axial gyro sensing firmware. With the patient in supine position, this application can detect changes in the sagittal and transverse planes of the body. The application was launched at the beginning of surgery. The initial pelvic position was calibrated as 0°/0° [0°- flexion/ extension tilt (sagittal plane), 0°- left/ right roll (transverse plane)]. It recorded the dynamic changes in pelvic position every 30 seconds during surgery with an accuracy of 1°. In the sagittal plane, posterior tilt or flexion was reported as negative and anterior tilt or extension as positive. In the transverse plane, roll to the side of surgery was reported as negative and to the opposite side as positive (Figure 2). THA using DAA was performed using a longitudinal or oblique (groin) incision. The intermuscular plane between the tensor fascia lata (TFL) and sartorius muscles was used to access the hip joint. A blunt cobra retractor was placed along the lateral border of femoral neck and a sharp cobra retractor was placed along the lateral aspect of proximal femur at this stage. The ascending branch of lateral circumflex femoral artery was ligated and cut. Subsequent soft tissue dissection was performed to expose the anterior hip capsule. A blunt cobra retractor along the medial border of femoral neck and a sharp cobra retractor along the anterior acetabular rim

Fig. 1. — An iPhone® 5 with PelvicTracker application mounted on contralateral iliac crest

were placed at this stage. The hip joint was exposed after anterior capsulectomy. Double osteotomy of the neck was performed and the femoral head was extracted after removing the wedge of bone. At this stage, a sharp cobra retractor at the antero-superior acetabular margin, a blunt cobra each, at the antero-inferior and postero-superior acetabular margins and a double pronged Mueller retractor along the postero-inferior acetabular margin were placed to expose the acetabulum (Figure 3). The double pronged Mueller retractor had to be often levered forcefully for an adequate acetabular exposure. This was especially true when the TFL muscle was bulky. Subsequently, the acetabulum was reamed and the acetabular component inserted using navigation. We aimed to put the cup in 45° ± 5° inclination and 20° ± 5° anteversion in relation to the supine FPP. The instance of cup insertion and the instantaneous position of the pelvis were recorded in the PelvicTracker application. The values of inclination and anteversion were recorded in the navigation system.We used uncemented acetabular components in all the hips. The implants were either Pinnacle®Duofix HA (DePuy, Warsaw, IN, USA),Trident® (Stryker, Mahwah, NJ, USA) or Deltamotion® (Titanium cup with Biolox delta® liner, DePuy, County Cork, Ireland). The liners were either highly cross linked polyethylene X3® (Stryker, Mahwah, NJ) or Biolox® delta Ceramax™ (Depuy, Warsaw, IN, USA). This was followed by femoral preparation. The femur was delivered out of the wound using a blunt hook and manoeuvres of hip adduction, extension, & external rotation. The following retractors were used during femoral preparation: double pronged Mueller retractor at the tip of the greater trochanter, sharp Hohmann's retractor along the posteromedial neck (calcar) and a sharp cobra along the lateral border of the neck (Figure 4). After preparation of the femoral cavity, cemented Exeter® (Stryker, Newbury, UK) or uncemented ABG® II (Stryker, Herouville Saint Clair, France) stem was inserted. Antibiotic Simplex® P (Stryker, Mahwah, NJ, USA) bone cement was used along with cemented stems. Biolox® delta ceramic (Stryker, Mahwah, NJ, USA) heads were used in all hips. Thus the bearings were either ceramic on ceramic or ceramic on polyethylene in all the hips. The wound was closed in layers.

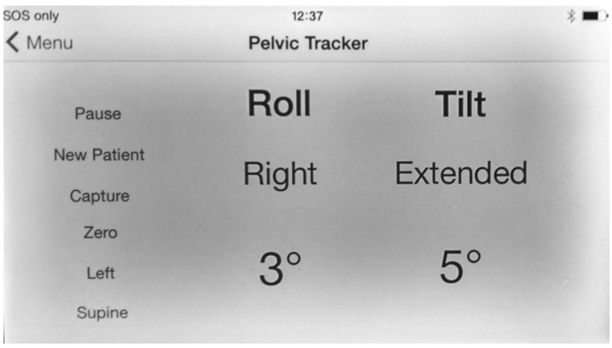

Fig. 2. — Screenshot displaying the intra- operative changes in pelvic position as recorded in the application

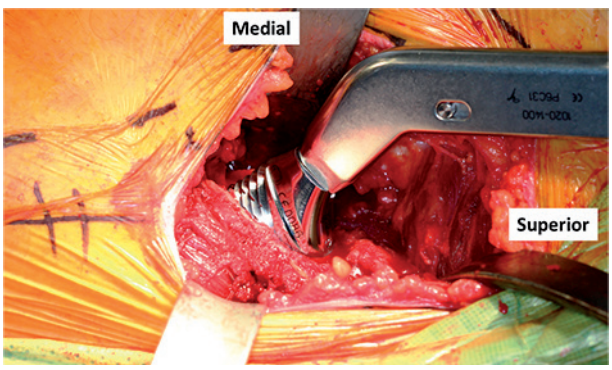

Fig. 3. — Placement of retractors for adequate acetabular exposure in a left THA using DAA. The red circle represents the double- pronged Mueller retractor placed postero- inferiorly and the blue circle represents the sharp cobra retractor placed antero- superiorly

Six week standing pelvic antero- posterior (AP) radiographs obtained in a standardized manner were evaluated for cup inclination and anteversion as per Lewinnek's method (5). We correlated changes in pelvic position with body mass index (BMI) and cup diameter.

Statistical analysis

Numerical data was subjected to descriptive analysis and expressed as mean ± standard deviation (SD), and range. Categorical data was analysed as frequency and percentage. Correlation was analysed using Pearson's correlation coefficient.Data was analysed using Microsoft Office Excel 2007 for Windows (version 12, Microsoft Corp; Redmond, WA).

RESULTS

The mean age of the patients was 70.7 years (Range: 58-89 years) with 6 males and 16 females. The right hip was operated in 13 patients and the left hip in 9 patients. The mean BMI was 25.2 (21 patients, Range : 18.4 to 27.8). The median cup diameter was 52 mm.

Changes in sagittal plane: The pelvis was extended as compared to the start of surgery in 19/ 22 hips at the time of cup implantation and the mean pelvic extension was 3.1° (Range: 1°-6°). Of the remaining 3 hips, the pelvis did not change in position in two and was flexed by 4° in one. Change in pelvic position of ≥ 5° in the sagittal plane was seen in 4/22 (18.2%) patients. The mean (± SD) pelvic change since the beginning of surgery was an extension of 2.5° ± 2.2° (Range : -4° to 6°).

Changes in transverse plane: The pelvis was rolled to the opposite side of surgery in 12 hips (Mean roll: 2.8°, Range : 1°-5°), to the same side of surgery in 8 hips (Mean roll : 3.9°, Range: 1°-9°) and unchanged in 2 hips at the time of cup implantation. Change in pelvic position of ≥ 5° in the transverse plane was seen in 4/ 22 (18.2 %) patients. The mean (± SD) change in pelvic position was a 0.1° ± 3.6° roll to the opposite side of surgery (Range : -9° to 5°).

Predicted change in anteversion: If the pelvis is tilted (change in sagittal plane) or rolled (change in transverse plane), this will primarily influence the anteversion of the acetabular component, whereas if the pelvis is oblique (change in coronal plane), this will mainly influence its inclination (*7*). Thus the changes determined in pelvic position by the PelvicTracker would primarily influence acetabular anteversion. We assumed that every 1° pelvic roll will change the cup version by 1° and every 1° change in tilt will change the cup version by 0.7° (*4*). Thus the intra- operative pelvic changes would have resulted in a mean (± SD) absolute change of 3.3° ± 2.3° (Range: 0.1°-7.2°) in anteversion. Predicted change in cup version of ≥ 5° was seen in 7/22 (31.8%) patients. The predicted change in acetabular version is in the functional or radiographic plane.

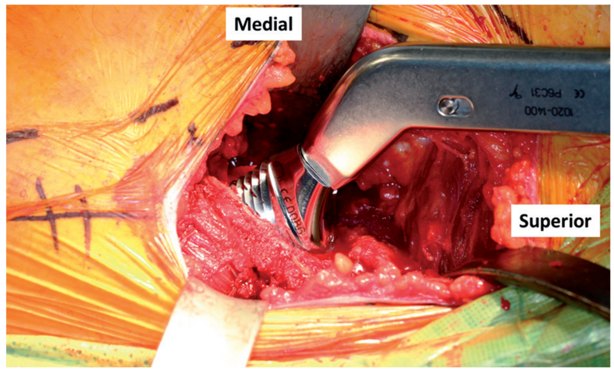

Fig. 4. — Placement of retractors for femoral exposure during left THA using DAA

The mean (± SD°) cup inclination and anteversion on 6 week AP radiographs were 44.8° ± 2.9° and 22.1° ± 2.2° respectively. BMI showed significant negative correlation with changes in sagittal plane (r = -0.482, p = 0.023) but no significant correlation with changes in transverse plane (r = 0.179, p = 0.437). There was no significant correlation between cup diameter and pelvic changes in either planes (sagittal: r = -0.246, p = 0.27; transverse: r = 0.111, p= 0.624).

DISCUSSION

The aim of our study was to determine if the pelvis changes in position during supine THA. Our study not only confirmed that it does change in position but also quantified the same in sagittal and transverse planes. We did not use any pelvic supports during surgery as the pelvis remains more or less stable in supine position. However, placement of acetabular retractors, forceful extraction of femoral head from the acetabulum, acetabular reaming and acetabular component impaction are some of the factors that can change pelvic position.

In terms of changes in sagittal plane, pelvic extension was consistently observed in 19/ 22 (86%) hips. We feel that placement of a double pronged Mueller retractor on the postero-inferior acetabular margin and levering it over the ischium and proximal femur against the TFL in order to expose the acetabulum results in a composite movement of extension and ipsilateral roll of the pelvis. As the Mueller retractor is levered in a postero- inferior direction, the femur is pushed posteriorly and laterally. This results in extension and ipsilateral pelvic roll of the pelvis due to an intact posterior capsule. Changes observed in transverse plane were not as consistent as the sagittal one with 12/22 (55%) pelvises rolling to the opposite side of surgery and 8/22 (36%) to the same side of surgery. It is difficult to pinpoint at any one cause resulting specifically in pelvic roll. But, we feel that the direction of pelvic roll is largely determined by the balance of forces between the sharp cobra retractor placed along antero-superior acetabular margin and the Mueller retractor placed along the postero- inferior acetabular margin (Figure 3). The sharp cobra retractor is under the reflected head of rectus femoris and iliopsoas tendon. Aggressive retraction with this sharp cobra levered against the strong tendons can roll the pelvis to the opposite side. The composite effect of these pelvic movements may result in a mean absolute change of 3.3° in anteversion, with nearly one third of the hips showing a change of ≥ 5° in anteversion. During non- navigated THA, surgeons usually aim to insert the acetabular component within a narrow range of anteversion like 15° ± 10° (*5*). The variation that may result from changes in intra- operative pelvic position as seen in our study may add an error to the surgeon's targeted orientation. Alternatively, use of computer navigation may be useful to obtain desired cup orientation as we did in our study.

Ezoe et al evaluated changes in pelvic position in 100 hips undergoing THA using translateral or posterolateral approach in lateral position (*2*). In the sagittal plane, they reported a mean forward inclination of 0.52° (Range : -12° to 15°) and 2.02° (-19° to 20°) with translateral and posterolateral approaches respectively. This is similar to our observation of mean extension (forward inclination) of 2.5° (Range : -4° to 6°) in the sagittal plane. In the transverse plane, they reported a mean internal rotation of 1.75° (Range : -1° to 8°) and 14.25° (Range : -4° to 31°) with translateral and posterolateral approaches respectively. In comparison, we found a mean roll of 0.1° (Range : -9° to 5°) to the opposite side (internal rotation) in the transverse plane. The difference between the findings of Ezoe et al (*2*) and our study is mainly due to the difference in patient positions and surgical approaches. It is interesting to note that the variability (Range) of pelvic position in the two planes was greater in their study as compared to ours. Although our sample size is smaller than theirs, we feel that the variability in our study is lesser due to greater stability offered by supine position as compared to lateral.

Grammatopoulos et al evaluated intra- operative pelvic movement during THA in lateral position in 67 hips using photogrammetric technique (*3*). They found a mean (± SD) angular deviation of 9° (± 6°) from the start of surgery until cup implantation. However, their software could not determine the 3D direction of movement. The mean pelvic changes and variability in sagittal (2.5° ± 2.2°) and transverse planes (0.1° ± 3.6°) in our study were lower than their study and are most likely due to difference in position and approaches.

We found a significant moderately negative correlation between changes in sagittal plane and BMI ($r = -0.482$, $p = 0.023$). This seems valid as the resistance of the pelvis to any movement should be proportional to the patient's BMI. Hence, greater the BMI, lesser should be the pelvic movement. However, we did not find any significant correlation between BMI and pelvic position changes in transverse plane. Although, our sample size is small and may not have sufficient power to detect any correlation, we feel that this finding was mainly due to inconsistency in pelvic position changes in the transverse plane. Nearly 55% pelvises had rolled to the same side of surgery, whereas 36 % of them had rolled to the opposite side at the time of cup implantation. We also evaluated correlation between cup diameter and changes in pelvic position in the two planes. Cup diameter is an indicator of hip size. We felt that larger cup diameter would mean larger surgical exposure. In addition, reaming with larger diameter reamers and insertion of a larger cup can also cause changes in pelvic position. But we failed to demonstrate any significant correlation between cup diameter and changes in pelvic position in either plane. This suggests that hip size does not influence intra- operative changes in pelvic position.

Our study has a couple of drawbacks. First, ours is a small sample size. But it is a homogenous population of patients undergoing surgery in the same position using the same approach & technique and by a single surgeon. Secondly, PelvicTracker can determine pelvic changes in the sagittal and transverse planes only. Since changes in the coronal plane could not be determined, we could not predict changes in cup inclination. Third, we have not taken into consideration the status of the spine while interpreting changes in pelvic position. Cases with stiff spine are likely to have lesser changes in pelvic position. Fourth, our presumption that the anteversion would change by 1° for every 1° pelvic roll may not be accurate. However, unlike the effect of pelvic tilt, there is no data regarding the effect of pelvic roll on cup anteversion. Fifth, the changes in pelvic position described in our study can be attributed specifically to our surgical technique. Alteration in surgical technique like choice and placement of retractors may result in a different pattern of pelvic change. But, to our knowledge, this is the first study that determines changes in pelvic position during supine THA. Sixth, the changes in pelvic position are in relation to the coronal or FPP of the patient in supine position. This may not be equivalent to the anatomic pelvic plane (determined by the two ASIS and symphysis pubis) in patients with a natural anterior or posterior pelvic tilt. This must be considered while interpreting the findings of our study.

In summary, pelvic position changes during supine THA despite the stability offered by this position. However, the magnitude and variability of change during supine THA is smaller as compared to lateral position. Nearly, one- fifth of the pelvises showed ≥ 5° changes in sagittal plane and a fifth showed ≥ 5° changes in transverse plane. These changes can result in variations of ≥ 5° in anteversion in nearly one third of the THAs. These changes can possibly introduce error in the surgeon's targeted acetabular component orientation. Whether, these apparently small changes have any clinical implications remains to be seen.

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