Acetabular Cup Placement in Navigated and Non-Navigated Total Hip Arthroplasty (THA): Results of Two Consecutive Series Using a Cementless Short Stem

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Background: *Acetabular component malposition has been linked to increased rates of dislocation, impingement, pelvic osteolysis, cup migration, leg length discrepancy, and polyethylene wear in patients undergoing total hip arthroplasty (THA).*
Objective: *Compare the acetabular component positioning and the operative time in two consecutive short-stem cementless THA series without and with using an imageless navigation.*
Material and Method: *The retrospective study consisted of 31 cases of short-stem cementless THA without navigation (NNAV) and 30 cases with navigation (NAV). CT scans were performed in all cases at two-month or later postoperatively. The abduction and anteversion angles measured on postoperative CT were compared between two groups using t-test. The percentage of cup placement (abduction, anteversion and combined) within the safe zone for each group was compared using Chi-square test at a 0.05 level of significance. The operative time was compared between two groups using t-test.*
Results: *The mean abduction was 43.97 (range, 33-52, SD 4.44) in NNAV group and 41.37 (range, 37-45, SD 2.01) in NAV group. This difference was significant (p = 0.004). The mean anteversion was 22.58 (range, 2-39, SD 10.68) in NNAV group and 13.57 (range, 7-18, SD 3.28) in NAV group. This difference was significant (p<0.001). According to the criteria of Lewinnek et al, 96.8% in NNAV group were placed within the safe zone for abduction, 51.6% for anteversion, and 48.4% for both abduction and anteversion. In NAV group, all 30 cups (100%) were placed within the safe zone for abduction, anteversion, and both. There were significant differences in the percentage of cup placement within the safe zone for anteversion (p<0.001), for both abduction and anteversion (p<0.001) but not significant for abduction (p = 0.32) between two groups. The mean operative time was 107.09 and 110.67 minutes for NNAV and NAV group respectively, this difference was not significant (p = 0.49).*
Conclusion: *The present study demonstrated a significant increase in the placement of acetabular cups within the safe zone using imageless navigation compared to freehand technique, especially at anteversion angle.*

Keywords: *Hip arthroplasty, Imageless navigation*

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Acetabular component alignment has been shown to be critical in regard to the overall success of total hip arthroplasty (THA). Variables such as age, sex, soft tissue quality, surgical approach, component bearing material and fixation methods play role in THA failure but malalignment may be one of the most important variable[1]. Malalignment of the acetabular component has been linked to increased rates of dislocation, impingement, pelvic osteolysis, cup migration, leg length discrepancy, and polyethylene wear in patients undergoing THA[2].

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Lewinnek et al[3] had defined a “safe zone” for the acetabular component placement, which they postulated would decrease the incidence of these complications. The safe zone widely accepted by various authors is abduction of 40°±10° and anteversion of 15°±10°. Freehand techniques rely on manual guides or the surgeon’s ability to estimate the cup orientation in relation to the patient’s position on the operating table. Using conventional techniques, placement within the safe zone, as described by Lewinnek et al[3], remains a challenge even for experienced surgeons. Callanan et al[4] determined the percent of optimally positioned acetabular cups in 1,823 hips, and demonstrated that 1,144 (63%) acetabular cups were within the abduction range, 1,441 (79%) were within the anteversion range and 917 (50%) were within the range for both. Digioia et al[5] demonstrated that 78% of cups in freehand technique were placed outside the safe zone.

Several researchers[6-8] had reported that imageless navigation was a safe and reliable technique and resulted in more precise cup placement compared to conventional freehand techniques. The accuracy of imageless navigation relies on accurate digitization of bony landmarks (anterior superior iliac spine (ASIS) and pubic tubercle) using a metal pointer. The imageless navigation uses the acquired landmarks to calculate an anterior pelvic reference plane (APP), yet overlying soft tissues, especially in obese patients, can obscure these landmarks and potentially introduce systematic error resulting in a tilting of the reference plane. Therefore, imageless navigation may not result in a significantly more precise cup placement compared to freehand techniques. Therefore, the purpose of the present study was to compare the acetabular component positioning in two consecutive short-stem cementless THA series by single surgeon without and with using an imageless navigation.

We hypothesized that navigation would significantly increase cup placement within the safe zone and significantly reduce outliers.

Material and Method

The present study was approved by the Ethic Committee of Maharat Nakhon Ratchasima Hospital. In late 2010, we started to perform short-stem cementless THA (Metha and Plasmacup SC; B. Braun Aesculap, Tuttlinggen, Germany) in our hospital with conventional freehand technique and in early 2012, navigated hip system was introduced. Because of the encouraging results in the literatures, we began managing our patients with navigator. We corrected the patients who were performed short-stem cementless THA with conventional freehand technique between March and December 2011 to compare the cup alignment with the patients who were performed THA with navigator between May and October 2012 by single surgeon (YS). The inclusion criteria were all patients who received short-stem cementless THA with or without navigation with appropriate postoperative CT scan in these periods. To reduced bias, we excluded patients during the first four months in both groups for early learning periods.

In non-navigated group, all procedures were performed in lateral decubitus position with modified Hardinge's approach. The short-stem cementless THA (Metha and Plasmacup SC; B. Braun Aesculap, Tuttlinggen, Germany) were used in all patients. Cup orientation was aimed at 40°±5° of abduction and 15°±5° of anteversion in all cases.

In navigated group, the short-stem cementless THA (Metha and Plasmacup SC; B. Braun Aesculap, Tuttlinggen, Germany) were used in all patients. All cases were performed in semilateral decubitus position with OrthoPilot THA plus 3.2 (cup only) software (Aesculap AG). A screw was inserted into the ipsilateral ASIS through a stab incision. The pelvic navigation tracker was attached to the screw. Bony landmarks (both ASIS and pubic symphysis) were determined and digitalized with a metal pointer to define anterior pelvic plane (APP). All patients were performed with modified Hardinge's approach. After removal of the femoral head, the deepest point of the acetabular fossa was registered as an additional reference point. Then using the trial cup, the natural abduction and anteversion of the acetabulum were determined. During reaming, the position of the reamer was acquired by the navigation system and surgeon was provided with real-time information about the resulting position of the reamer (medialization, cranialization, and antero-poserior direction) and its orientation (abduction and anteversion) in relative to APP as well as to the previously acquired acetabulum. After reaching the design reaming position, the final cup was put in place, the surgeon was provided with real-time information about the cup position and orientation. Cup orientation was aimed at 40°±5° of abduction and 15°±5° of anteversion in all cases. The final cup position was saved by the navigation system. After finishing the cup, the femoral stem was inserted by conventional freehand technique as in non-navigated group.

Postoperatively, a multislice computed tomographic (CT) scan was obtained at two months or later for abduction and anteversion angle measurement. The largest cup diameter on the coronal plane was identified and the abduction angle was measured (Fig. 1A). The anteversion angle was measured by identifying the largest cup diameter on an axial plane (Fig. 1B). All measurements were performed three times and averaged by PC who was not involved with the surgery. The demographic data such as age, gender, body mass index (BMI), diagnosis, and operative time were recorded and compared between two groups.

Statistical analysis

According to the results of previously published data[5], standard deviation of abduction

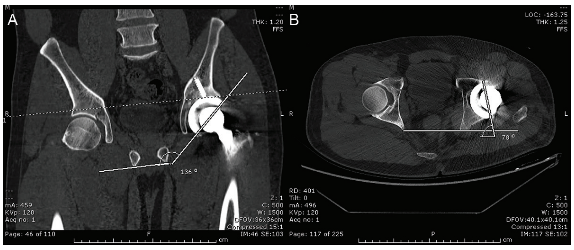

Fig. 1 Postoperative CT-scan evaluation of final cup alignment A) abduction and B) anteversion.

and anteversion measurements are expected to be about 4° and 6° for navigation and about 7° and 14° for freehand technique methods. Power calculations revealed that a group sample size of 30 patients would be sufficient to detect such a clinically relevant difference in variability with 80% power using Levene's test for equality of variance at a two-sided 0.05 level of significance.

Mean cup abduction and anteversion between two groups were compared using t-test. The percentage of cup placement (abduction, anteversion and both) within the safe zone in each groups were compared using Chi-square tests. Means and SDs of the demographic data in both groups were calculated and compared using t-test. A level of $p<0.05$ was selected as the level of significance in all analyses.

Results

Non-navigaged group

Thirty-one cases were in the present study group. The mean patient age was 45.5 years (range, 24-59, SD 10.4), 64.5% were men. The main indication was osteonecrosis of the femoral head (ONFH) (83.9%). The mean BMI was 23.63 (range, 18-32.3, SD 4.05). The mean operative time was 107.09 minutes (range, 80-120, SD 11.8) (Table 1).

The mean cup placement for abduction was 43.97 (range, 33-52, SD 4.44). According to the criteria of Lewinnek et al[3], 30 (96.8%) from 31 cups were placed within the safe zone for abduction. The mean cup placement for anteversion was 22.58 (range, 2-39, SD 10.68). According to the criteria of Lewinnek et al[3], 16 (51.6%) from 31 cups were placed within the safe zone for anteversion. Taking both abduction and anteversion into consideration, 15 (48.4%) from 31 cups were placed within the safe zone (Table 2) (Fig. 2).

Navigated group

Thirty cases were in the present study group. The mean patient age was 45.03 years (range, 23-68, SD 12.9), 86.7% were men. The main indication was osteonecrosis of the femoral head (ONFH) (86.7%). The mean BMI was 21.4 (range, 16.2-28.3, SD 3.17). The mean operative time was 110.67 minutes (range, 80-210, SD 26.2) (Table 1).

Table 1. Demographic data

	Non-navigated THA (n = 31)	Navigated THA (n = 30)	*p*-value
Operating period	March to December 2011	May to October 2012	
Male	64.5%	86.7%	0.04
Age (years), mean (SD)	45.50 (24-59, 10.4)	45.03 (23-68, 12.9)	0.87
Mean BMI (range, SD)	23.63 (18-32.3, 4.05)	21.40 (16.2-28.3, 3.17)	0.02
Diagnosis	83.9% ONFH	86.7% ONFH	0.76
Mean operative time (minutes) (range, SD)	107.09 (80-120, 11.8)	110.67 (80-210, 26.2)	0.49

THA = total hip arthroplasty; BMI = body mass index; ONFH = osteonecrosis of the femoral head

Table 2. Overview of results

	Non-navigated THA (n = 31)	Navigated THA (n = 30)	*p*-value
Mean abduction and anteversion			
Mean abduction (range, SD)	43.97 (33-52, 4.44)	41.37 (37-45, 2.01)	0.004
Mean anteversion (range, SD)	22.58 (2-39, 10.68)	13.57 (7-18, 3.28)	<0.001
Safe zone placement			
Abduction	30/31 (96.8%)	30/30 (100%)	0.32
Anteversion	16/31 (51.6%)	30/30 (100%)	<0.001
Abduction and anteversion	15/31 (48.4%)	30/30 (100%)	<0.001

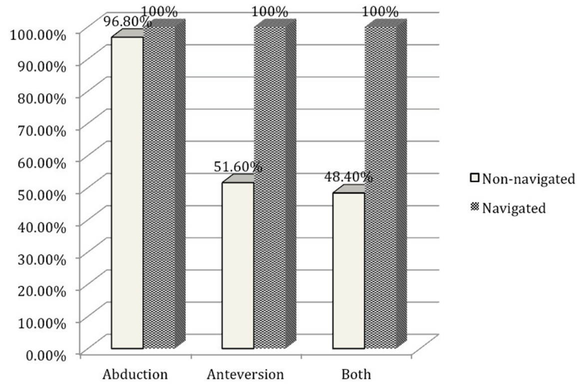

Fig. 2 The percentage of safe zone placement for abduction, anteversion and both for non-navigated and navigated groups.

The mean cup placement for abduction was 41.37 (range, 37-45, SD 2.01). According to the criteria of Lewinnek et al[3], all cups were placed within the safe zone for abduction. The mean cup placement for anteversion was 13.57 (range, 7-18, SD 3.28). According to the criteria of Lewinnek et al[3], all cups were placed within the safe zone for anteversion. Taking both abduction and anteversion into consideration, all cups were placed within the safe zone (Table 2) (Fig. 2).

There was significant difference of mean abduction ($p = 0.004$) and mean anteversion ($p<0.001$) between two groups. Chi-square test revealed no significant difference in the proportion of correctly placed cups for cup abduction ($p = 0.32$; 96.8% non-navigated and 100% navigated) but significant difference in the proportion of correctly placed cups for cup anteversion ($p<0.001$; 51.6% non-navigated and 100% navigated) and both abduction an anteversion ($p<0.001$; 48.4% non-navigated and 100% navigated). There was no significant difference between mean operative time between two groups ($p = 0.49$; 107.09 in non-navigated and 110.67 in navigated).

Discussion

Acetabular component malalignment has been implicated for various complications of total hip arthroplasty including impingement, dislocation, early wear and loosening[2]. Lewinnek et al[3] had defined a "safe zone" for the acetabular component placement, which they postulated would decrease the incidence of these complications. Previous studies had reported a significant increase in accurate cup placement with imageless navigation system. In this respect, Kalties et al[6] demonstrated that safe zone placement was increased from 14 of 30 acetabular cups with conventional technique to 28 of 30 acetabular cups with imageless navigation. Parratte and Argenson[7] demonstrated that 57% of conventional technique and 20% of navigation were placed outside the safe zone. This difference was significant. Hohmann et al[8] demonstrated a significantly increased the percentage of correctly placed cups within the safe zone, overall placement for navigated cups for both abduction and anteversion increased to 76.6% compared to only 20% with conventional technique. Similarly, Najarian et al[9] demonstrated a significant reduction in variation from desired cup position with imageless navigation.

Gandhi et al[10], in a meta-analysis, demonstrated that the number of acetabular outliers in the navigation group was 15/140 (10.7%) compared to 46/110 (41.8%) in the freehand group, this difference was statistically significant. They concluded that navigation in total hip arthroplasty improved the precision of acetabular cup placement by decreasing the number of outliers from the designed alignment. Moskal and Capps[11], in an evidence-based analysis, demonstrated that there was a statistically significant difference in the incident of acetabular component placement in the safe zone, with navigated having significantly more "safe placement" than non-navigated. In addition, navigated had significantly fewer dislocations than non-navigated.

Consistent with our results, we demonstrated that 30 (96.8%) from 31 cups of non-navigated (NNAV) group were placed within the safe zone for abduction, 16 (51.6%) were placed within the safe zone for anteversion and 15 (48.4%) were placed within the safe zone for both abduction and anteversion. In navigated (NAV) group, all 30 cups (100%) were placed within the safe zone in abduction, anteversion and both. Chi-square test revealed significant differences in the proportion of cup placement within the safe zone for anteversion ($p<0.01$; 51.8% NNAV and 100% NAV), for both abduction and anteversion ($p<0.01$; 48.4% NNAV and 100% NAV) but no significant for abduction ($p = 0.32$; 96.8% NNAV and 100% NAV).

Several researchers demonstrated that imageless navigation increased the operative time when compared with conventional freehand technique. Kalties et al[6] demonstrated that the operative time was increased by eight minutes with imageless navigation ($p = 0.11$). Parratte and Argenson[7] demonstrated that navigation took a mean of twelve minutes longer than freehand technique. Lin et al[12] demonstrated that navigation resulted in an average additional 21 minutes of surgical time. Consistent with our results, we demonstrated that the mean operative time was 107.09 (range, 80-120, SD 11.8) and 110.67 (range, 80-210, SD 26.2) minutes for NNAV and NAV group respectively, this difference was not significant ($p = 0.49$).

There were some limitations of the present study. (1) There were limit number of patients and (2) the present study was retrospective which compared two cohorts rather than two randomized groups. Despite these limitations, the results were of value because the present study included patients treated by single surgeon at a single institution using the same implants and we used CT-scan for evaluation the cup alignment postoperatively, which was the gold standard.

Conclusion

The present study demonstrated a significant increase in the correct placement of acetabular cups within the safe zone using imageless navigation compared to freehand technique, especially anteversion angle. The navigation took longer in the operation, but it did not made a significant difference.

What is already known on this topic?

Malalignment of the acetabular component has been linked to increased rates of dislocation, impingement, pelvic osteolysis, cup migration, leg length discrepancy, and polyethylene wear in patients undergoing THA[2]. Lewinnek et al[3] have defined a "safe zone" for the acetabular component placement that should decrease the incidence of these complications. The safe zone widely accepted by various authors is abduction of 40°±10° and anteversion of 15°±10°. Freehand techniques rely on manual guides or the surgeon's ability to estimate the cup orientation in relation to the patient's position on the operating table. Using conventional techniques, placement within the safe zone, as described by Lewinnek et al[3], remains a challenge even for experienced surgeons.

What this study adds?

This study demonstrated a significant increase in the placement of acetabular cups within the safe zone using imageless navigation compared to freehand technique, especially the anteversion angle.

Potential conflicts of interest

None.

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การศึกษาเปรียบเทียบมุมของเบ้าสะโพกเทียมแบบใช้และไม่ใช้คอมพิวเตอร์นำร่องช่วยผ่าตัด

ยิ่งยง สุขเสถียร, รัชวรรณ สุขเสถียร, ปรเมษฐ์ ชัยวิรัตนะ

ภูมิหลัง: *มุมของเป้าข้อสะโพกเทียมผิดตำแหน่งมีผลต่อการเคลื่อนหลุดและการสึกกร่อนของข้อสะโพกเทียม*
วัตถุประสงค์: *ศึกษาเปรียบเทียบมุมของเบ้าสะโพกเทียมในผู้ป่วยที่ใช้และไม่ใช้คอมพิวเตอร์นำร่องช่วยผ่าตัด*
วัสดุและวิธีการ: *ศึกษาในผู้ป่วยผ่าตัดแบบไม่ใช้คอมพิวเตอร์นำร่อง 31 ราย และใช้คอมพิวเตอร์นำร่อง 30 ราย โดยเปรียบเทียบมุม abduction และ anteversion ของเบ้าสะโพกเทียม*
ผลการศึกษา: *ค่าเฉลี่ยมุม abduction เท่ากับ 43.97 องศา ในกลุ่มที่ไม่ใช้คอมพิวเตอร์นำร่อง และเท่ากับ 41.37 องศา ในกลุ่มที่ใช้คอมพิวเตอร์นำร่อง ค่าเฉลี่ยมุม anteversion เท่ากับ 22.58 องศา ในกลุ่มที่ไม่ใช้คอมพิวเตอร์นำร่อง และเท่ากับ 13.57 องศา ในกลุ่มที่ใช้คอมพิวเตอร์นำร่อง ค่ามุม anteversion เข้าช่วงปลอดภัยในกลุ่มที่ใช้คอมพิวเตอร์นำร่องมากกว่ากลุ่มที่ไม่ใช้คอมพิวเตอร์นำร่องอย่างมีนัยสำคัญ*
สรุป: *การใช้คอมพิวเตอร์นำร่องช่วยผ่าตัดทำให้ค่ามุม anteversion ของเบ้าสะโพกเทียมเข้าช่วงปลอดภัยมากกว่าไม่ใช้คอมพิวเตอร์นำร่อง*