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Does Robotic-Assisted Computer Navigation Affect Acetabular Cup Positioning in Total Hip Arthroplasty in the Obese Patient? A Comparison Study

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ABSTRACT

Obese populations present challenges for acetabular cup placement during total hip arthroplasty (THA). This study examines the accuracy of acetabular cup inclination and version in the obese patient with robotic-assisted computer navigation. A total of 105 patients underwent robotic-assisted computer navigation THA with a posterior approach. Groups were divided on body mass index (BMI, kg/m^2) of <30, 30–35, and >35. There was no statistical difference between the BMI <30 (n = 59), BMI 30–35 (n = 34) and BMI >35 (n = 12) groups for acetabular inclination ($P = 0.43$) or version ($P = 0.95$). Robotic-assisted computer navigation provided accurate and reproducible placement of the acetabular cup within safe zones for inclination and version in the obese patient.

Obesity remains a significant challenge to medical practitioners as the worldwide obesity rate has nearly doubled since 1980 [1]. According to the World Health Organization (WHO) over 500 million people worldwide are considered obese. The WHO's definition of obesity is calculated by the body mass index (BMI) defined as a person's weight in kilograms divided by the square of his height in meters (kg/m^2). A BMI ≥25 kg/m^2 is overweight, and a BMI ≥30 kg/m^2 is obese. Obesity is subdivided into class I (30–34.9 kg/m^2), class II (35–39.9 kg/m^2), and class III (≥40 kg/m^2) which is defined as “morbid obesity.” Obesity is a major risk factor for noncommunicable diseases such as cardiovascular disease (heart disease and stroke), diabetes, musculoskeletal disorders (including osteoarthritis), and some cancers (endometrial, breast, and colon). Total hip arthroplasty (THA) in the obese patient presents a unique set of challenges to the surgeon. Morbid obesity has been shown to increase mean operative time for total hip arthroplasty [2]. The risk for dislocation in THA has also been shown to be increased in obese patients [3,4]. Component positioning in the obese patient can present a challenge to surgeons. Malpositioning of the acetabular cup can result in increased risk for dislocation, higher bearing surface wear, and component instability [5–7].

Historically, “safe zones” for acetabular cup position were defined by Lewinnek et al [8] which consisted of cup orientation with an anteversion of 15 ± 10 degrees and abduction of 40 ± 10 degrees. Callanan et al [9] also provided guidelines for an acceptable range for acetabular cup positioning with respect to abduction (30–45 degrees) and version (5–25 degrees). Barrack et al [10] performed a multivariate regression analysis on their acetabular cup position on 1549 total hip arthroplasties and found that BMI ≥30 was a risk factor for component malpositioning. The odds for malpositioning increased by ≥0.2 for each 5 kg/m^2 increase in BMI.

At our institution, we have implemented the use of robotic-assisted computer navigation with total hip arthroplasty to further improve accuracy for component positioning. The purpose of this study was to evaluate whether obesity affects accuracy of acetabular cup positioning using robotic-assisted computer navigation. Our hypothesis was that with the use of robotic-assisted computer navigation, there would be no difference in accuracy of cup position between obese and non-obese patients. This study has received institutional review board (IRB) approval.

Materials and Methods

During the study period, June 2011 to August 2013, data were collected prospectively on all patients undergoing primary total hip arthroplasty using robotic-assisted computer navigation by the senior surgeon (XXX). There were 105 robotic-assisted THAs performed by the senior author during this time. The senior surgeon helped design

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the study and performed the procedures but was not involved in writing the manuscript or data analysis. Inclusion criteria were patients who underwent posterior-approach THA during the study period with the use of robotic-assisted computer navigation. We used the MAKO™ robotic hip system (MAKOplasty® total hip application; MAKO™ Surgical Corporation, Ft. Lauderdale, FL, USA), which is a robotic-assisted computer navigation that uses the RIO® (Robotic Arm Interactive Orthopedic System) for both reaming the acetabulum during bone preparation and cup placement.

Pre-Operative Planning

Patients who were scheduled for THA underwent pre-operative planning on plain radiographs to determine component position and sizes, level of the neck cut, and amount of leg lengthening or shortening needed. All patients completed a CT scan of the involved hip and knee pre-operatively. A 3-D patient-specific model of the pelvis and proximal femur was created by the robotic system which was used to determine component positioning and sizing. This template also served as a comparison for a three dimensional computer based model built from the CT scan. The senior surgeon (XXX) completed all templates with acetabular components planned at 40 degrees of inclination and 20 degrees of anteversion prior to each case.

Surgical Technique

Patients were positioned in the lateral decubitus position and a 10–12 cm incision was made for a standardized mini-posterior operative approach. The hip was dislocated and a navigation pin was placed in the greater trochanter for femoral registration. The femoral neck osteotomy is navigated and created and the femur was prepared for an uncemented implant. The acetabulum was then exposed and registered using three navigation pins and an array in the iliac crest. The navigation system adjusted for pelvic tilt and rotation. This system used a haptic robotic arm that guided acetabular reaming and cup placement and provided the surgeon with feedback regarding cup placement, stem version, leg length, and global offset. The hip was then trialed for stability. During the study period no acetabular components required a change in position due to instability.

Implants

All robotic assisted THAs used the Restoris Trinity acetabular component (Corin Group PLC®, Cirencester, UK). The femoral components utilized either the Restoris Metafix (Corin Group PLC®, Cirencester, UK) or Smith & Nephew Anthology (Smith & Nephew®, London, UK) stem depending on preoperative templating.

Radiographic Measurements

Two-weeks post-operatively, patients presented to clinic and completed a supine AP pelvic radiograph. This was used to measure acetabular inclination and anteversion. Radiographs were discarded if the symphysis rotated greater than 10 mm from the coccyx. If this occurred, a radiograph from the three-month follow-up visit was used for measurement. The measurements were obtained using Trauma-Cad™ software (build number 2.2.535.0, 2012, Voyant Health®, Petach-Tikva, Israel). This software allows measurement of cup inclination and version on the AP pelvis and has been previously validated [11]. All radiographs were interpreted by an independent observer who was blinded to groups. Previous radiographic measurements have been evaluated using this technique for intra-observer and inter-observer reliabilities and shown to have satisfactory correlation ($r > 0.82$ and $P < 0.001$) [12].

Statistical Analysis

Acetabular cup positioning was analyzed between patients with BMI <30 and BMI ≥30 (obese class I) and also between patients with BMI <35 and BMI ≥35 (obese class II). Lewinnek and Callanan safe zones were used to calculate outliers for each group. ANOVA testing was used to calculate significance between BMI groups and chi-square tests were conducted for categorical data. P values of <0.05 were considered statistically significant. We also present the percent of patients who fell outside the classification of Lewinnek and Callanan. Fisher's exact test was used to calculate a difference between BMI groups of patients who fell out of either Lewinnek or Callanan safe zones. Pearson's and Spearman's correlation coefficients were calculated between BMI and version, and BMI and inclination. Descriptive statistics were performed using Microsoft Excel (Redmond, WA).

Results

Demographics

A total of 105 patients were included in this study, of which 46 were male and 59 were female (Table 1). There were 20 normal weight patients (BMI <25), 39 overweight patients (BMI 25–30), 34 class I obese patients (BMI 30–35), 8 class II obese patients (BMI 35–40), and 4 class III obese patients (BMI >40). When stratifying the groups, there were 59 patients with BMI <30, 34 patients with BMI 30–35, and 12 patients with BMI >35 (Table 1). The height was 67.7 inches for the BMI <30, 67.9 inches for the BMI 30–35 group, and 68.5 inches for BMI >35 and not statistically significant with ANOVA testing ($P = 0.82$). A comparison of operating time for the BMI <30 (66.4 minutes), BMI 30–35 (73.1 minutes), and BMI >35 (80 minutes) groups was also not statistically significant ($P = 0.14$).

Imaging Findings

Scatter plots for acetabular cup version (Fig. 1) and inclination (Fig. 2) are presented for all patients. When evaluating the BMI <30 group, there were 2 (3.4%) patients who fell outside of Lewinnek's safe zones, and 4 (6.8%) patients who fell outside Callanan's safe zones. There were no patients in the BMI 30–35 and BMI >35 groups outside of the Lewinnek and 2 (4.3%) patients in the outside of the Callanan safe zone in the BMI 30–35 group with none in the BMI >35 group (Fig. 3). The difference in number of patients outside of the Lewinnek ($P = 0.63$) or Callanan ($P = 0.99$) safe zones was not significant using Fisher's exact test. The BMI <30 group had a mean acetabular cup inclination of 39.9 ± 3.0 degrees and version of 16.8 ± 4.0 degrees. The BMI 30–35 group had a mean acetabular cup inclination of 39.72 ± 3.29 degrees and version of 17.02 ± 3.6 degrees. The BMI >35 group had a mean acetabular cup inclination of 41.02 ± 2.27 and version of 16.73 ± 2.74. ANOVA calculation of acetabular inclination ($P = 0.43$) and version ($P = 0.95$) did not show a significant difference between groups or correlation over the entire cohort (Table 2). When calculating Pearson's and Spearman's correlation coefficients between BMI and version, and BMI and acetabular inclination, all values did not show

Table 1
Demographics.

	BMI <30	BMI 30–35	BMI ≥35	*P*-Value
Male	20	17	9	0.27
Female	39	17	3	
Total	59	34	12	
Height (inches)	67.69	67.71	68.50	0.82
Weight (lb)	171.22	209.85	259.17	<**.001**
BMI (kg/m^2)	26.14	32.03	38.65	<**.001**

Values in boldface indicate the *P*-value <.05 resulting in a statistically significant difference between the reported values.

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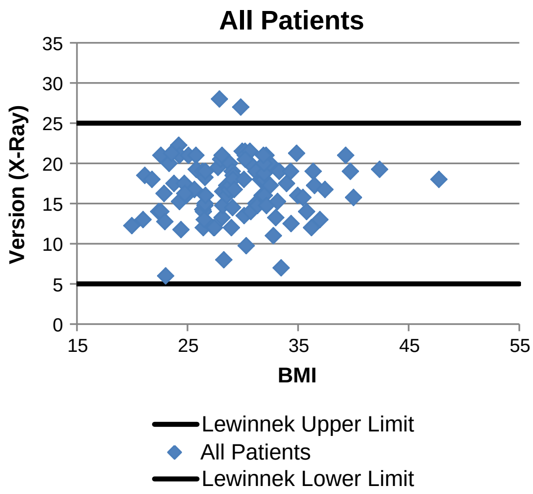

Fig. 1. Acetabular cup version scatterplot for all patients in the study.

any statistical significance for each BMI category, and for the overall cohort (Tables 3 and 4).

A power analysis was performed (Table 5) comparing the power of study with respect to acetabular inclination and version between all the BMI groups. Both calculation were found to be underpowered (inclination = 0.39, version = 0.08).

Discussion

To our knowledge, we present the first case-controlled radiographic study comparing acetabular cup inclination and version in an obese patient population using robotic-assisted computer navigation. Our study did not show any significant difference between acetabular cup inclination and version between groups when comparing BMI <30, BMI 30–35 or BMI ≥35. Additionally, we did not find a significant increase in operative time between all three groups.

One of the advantages of robotic-assisted computer navigation in total hip arthroplasty is that it primarily uses the registration of easily identifiable bony landmarks as reference points. This can aid surgeons when performing such procedures in an obese patient where the soft-tissue envelope may provide difficulty in correct implant positioning.

With the growing epidemic of obesity, there has been increased emphasis placed on the challenges of total hip arthroplasty in this patient population. Elson et al [13] performed a matched-control study evaluating acetabular cup positioning in the morbidly obese population without the use of computer navigation. They found a significant correlation between morbid obesity with respect to under-anteversion and a trend toward over-abduction of the acetabular cup placement. Similarly, Barrack et al [10] evaluated 1549 patients and found that the risk of component malposition increased by ≥0.2 for every 5 kg/m^2 increase in BMI.

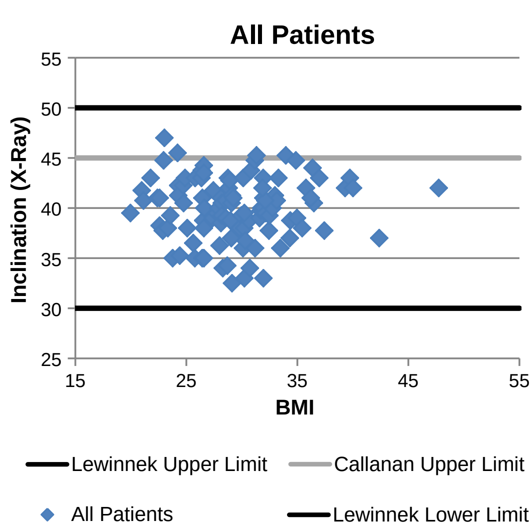

Fig. 2. Acetabular cup inclination presented for all patients.

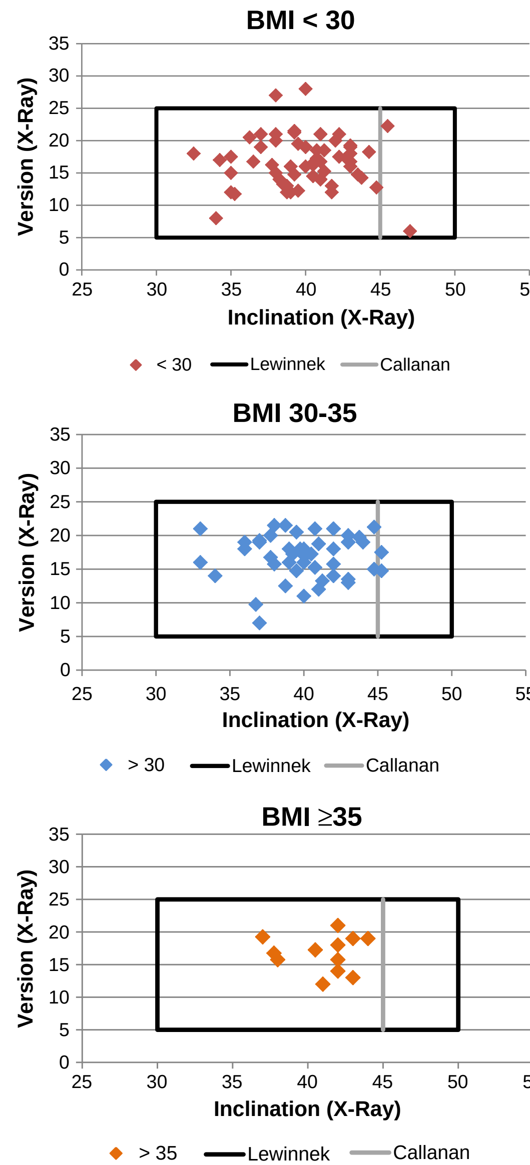

Fig. 3. Scatterplot of BMI <30, BMI 30–35, and BMI >35 with acetabular cup version on the y-axis and inclination on the x-axis. Lewinnek's "safe zone" for cup placement is outlined by the box in both scatterplots.

Table 2
Radiographic Measurement of Acetabular Cup Inclination and Version of BMI <30, BMI 30–35, and BMI ≥35 Groups.

	BMI < 30 (n = 59)	BMI 30-35 (34)	BMI ≥ 35 (n = 12)	P-value
Inclination	39.89 ± 3.02	39.72 ± 3.29	41.02 ± 2.27	0.43
Spearman's coefficient (all groups)			0.01	0.92
Version	16.78 ± 3.96	17.02 ± 3.60	16.73 ± 2.74	0.95
Spearman's coefficient (all groups)			0.06	0.54

ANOVA was used to compare means between groups with $P < .05$ considered statistically significant.

Table 3
Calculation of Pearson's and Spearman's Correlation Coefficient for BMI and Inclination for Each BMI Group.

Correlation Between BMI and Inclination	BMI <30 (n = 59)	BMI 30–35 (n = 34)	BMI ≥35 (n = 12)	Total
Pearson's	−0.22	0.24	0	0.03
P-value	0.09	0.17	1.00	0.75
Spearman's	−0.21	0.20	0.01	0.01
P-value	0.12	0.25	0.97	0.92

Wang et al [14] recently compared intra-operative time measurements in patients grouped by the WHO classification of BMI. They found that operating time increased progressively with increasing BMI category. Significant differences were found between normal weight patients and all 3 obesity groups in total room and surgery times. The use of robotic-assisted computer navigation in our study has been shown to not affect surgical time with increasing obesity.

Computer navigation systems for total hip arthroplasty have shown improved accuracy for placement of acetabular cups within the desired safe zones [15–19]. Tsukada and Wakui [20] evaluated the accuracy of acetabular cup placement for imageless navigation in obese patients. They found that the error in anteversion was significantly higher in the obese group than the non-obese group. They defined obesity as BMI ≥25. In our study, we used higher BMI levels as our cutoffs (30 kg/m^2 and 35 kg/m^2). To our knowledge there has not been any reported studies looking at the obese and morbidly obese patient population with regard to acetabular cup placement using robotic-assisted computer navigations systems. We utilized a robotic-assisted computer navigation system which we theorize should provide even more improved accuracy over current imageless navigation systems due to intra-operative haptics provided during robotic-assisted acetabular reaming and cup placement.

The strengths of our study include the fact that to our knowledge this is the first published study comparing the placement of the acetabular cup in total hip arthroplasty in an obese to a non-obese patient population using robotic-assistance. We were able to evaluate cup placement based on both Lewinnek and Callanan's safe zones for all groups. Additionally, we were able to subcategories and compare obese class I and class II groups with regard to acetabular cup placement. While we have a control group, one weakness of the study is the fact that we did not perform a matched case–control series. Additionally, we only evaluated patients undergoing total hip arthroplasty with a posterior approach and did not evaluate patients who underwent anterior approach. This could theoretically present more challenges in the obese patient. Another weakness in the study is the use of CT scans for preoperative planning and evaluation and the utilization of radiographs for postoperative measurement of acetabular cup inclination and version with the use of Trauma-Cad™ software. We were cognizant of the risks of higher radiation exposure with subsequent CT scans postoperatively and therefore decided to obtain radiographs. Lastly, our power analysis did show that our study was under-powered. While the use of robotic-assisted computer navigation is gaining popularity, at the time of our study, we were limited to the sample size of our initial 105 patients. Therefore, further higher volume studies will need to be published to further accurately determine the efficacy of the technology. However, our study is the first study to evaluate the use of robotic hip replacement in the higher BMI patient, and showed promising results for accuracy in total hip arthroplasty. Future studies should focus on if there is indeed a difference in surgical approaches with respect to cup placement and operative time using robotic-assistance total hip arthroplasty.

Table 4
Calculation of Pearson's and Spearman's Correlation Coefficient for BMI and Version for Each BMI Group.

Correlation Between BMI and Version	BMI <30 (n = 59)	BMI 30–35 (n = 34)	BMI ≥35 (n = 12)	Total
Pearson's	0.18	−0.16	0.44	0.08
P-value	0.18	0.38	0.15	0.45
Spearman's	0.13	−0.20	0.54	0.06
P-value	0.34	0.27	0.07	0.54

Table 5
Power Analysis to Calculate Statistical Significant Difference Comparing BMI Groups for Acetabular Inclination and Version.

BMI Groups	Power Analysis for Inclination	Power Analysis for Version
BMI <30, BMI 30–35, and BMI ≥35	0.39	0.08

Conclusion

Robotic-assisted total hip arthroplasty provides accurate and reproducible placement of the acetabular cup with respect to safe zones for inclination and version in the obese patient. While previous literature has shown obesity to be associated with decreased accuracy of cup placement in conventional hip arthroplasty, the current series of robotic-assisted arthroplasties found that higher BMI did not compromise accuracy of cup placement. Additionally, there was no significant difference in operative time between groups when stratified by obese class I and class II patients.

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