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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.