Are Morbidly Obese Patients Undergoing Total Hip Arthroplasty at an Increased Risk For Component Malpositioning?

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A B S T R A C T

Acetabular cup positioning is a critical factor in determining adverse clinical outcomes in THA. This evaluation was performed to determine if morbid obesity (BMI ≥ 35 kg/m²) is a contributing risk factor to cup malpositioning. Two groups of patients were obtained from a local arthroplasty registry and match-controlled for gender, age, and diagnosis (n = 211 morbidly obese; n = 211 normal). Intraoperative data and postoperative AP pelvis and cross-table lateral radiographs were obtained for each patient. The Martell Hip Analysis Suite was used to calculate cup positioning (successful positioning defined as 30°–45° of abduction, and 5°–25° of anteversion), as well as varus–valgus alignment of the femoral stem. There was a significant correlation between morbid obesity with respect to underanteversion; using multivariate analysis, there was a trend toward a combined underanteversion/overabduction of the acetabular cup. Of all variables considered, high BMI was the most significant risk factor leading to malpositioning.

Total hip arthroplasty (THA) is a highly successful surgical procedure that has experienced a steady increase in demand during recent years. According to the Agency for Healthcare Research and Quality, THA currently accounts for more than 285,000 orthopedic procedures performed in the United States annually, a number that is forecasted to double in the next two decades [1]. Considering the notable projected increase in demand for THA, a priority must be placed on identifying and evaluating common indicators of adverse clinical outcomes.

Optimal acetabular cup position is an important factor in the long-term survivorship of THA [2–4]. Malpositioning of the acetabular component has been associated with a number of adverse clinical outcomes including dislocation, increased wear, squeaking in ceramic-on-ceramic bearing surfaces, fracturing of the polyethylene liner, and adverse tissue reactions with edge-loading in metal-on-metal [5–11]. Although debate is currently ongoing with respect to the definition of an “optimal” range of abduction and version angles, a recent publication by Callanan et al [12] has posited that the “optimal” positioning of the acetabular cup should be within 30°–45° abduction, and 5°–25° anteversion. That same study evaluated the role of various clinical and demographic factors on the incidence of cup malpositioning in a large cohort of patients. One of the principle findings of the study suggested an increased risk of cup malpositioning in clinically obese patients, defined by the World Health Organization (WHO) as patients with a body mass index (BMI) ≥ 30 kg/m². This finding is disconcerting, particularly considering the potential combined effect of increased demand for THA in patients with limited mobility and the noted rise in obesity in the United States in recent years.

The concern of clinical obesity is amplified by the concurrent rise in patients categorized as morbidly obese, having a BMI ≥ 35 kg/m². A recent report released by the Center for Disease Control (CDC) projected obesity rates to reach as high as 42% by 2030 in the United States [13]. As the number of morbidly obese patients grows each year in concert with the rising demand for THA, surgeons will be required to contend with the difficulties inherent in treating this population. Aside from known comorbidities associated with morbidly obese patients such as deep-vein thrombosis (DVT) and cardiovascular complications, the presence of excess adipose tissue significantly increases the difficulty of ensuring optimal component placement for the arthroplasty surgeon [14,15]. The purpose of this study was to compare the rate of cup malpositioning between patients classified as morbidly obese (BMI ≥ 35 kg/m²) and the study control group (BMI 18.9–24.9 kg/m²), as well as identify any potential risk factors associated with cup malpositioning in the morbidly obese cohort. We were also interested in evaluating any differences in varus–valgus femoral stem alignment between the morbidly obese and study control group.

Patients/Methods

Using a hospital-based arthroplasty registry, data were analyzed from two different groups of patients. The first group included 211 consecutive patients (220 hips) with a BMI of ≥ 35 kg/m² (morbidly obese), who received a primary THA at a tertiary hospital,
Postoperative anteroposterior pelvis (AP pelvis) and cross-table lateral radiographs were obtained for all patients and measured in the Martell Hip Analysis Suite™ (HAS) in order to calculate abduction and version angle of the acetabular component. HAS utilizes edge-detection software to identify outlines of the acetabular component based on a series of user-designated clicks around the cup opening, the femoral head, and the ischial tuberosities. Three laboratory technicians completed an extensive validation process on a set of 20 practice films before using the software to measure the study films. All HAS measurements were reviewed and approved by another validated user prior to entry into the study. Cross-table lateral radiographs were reviewed to confirm whether the cup was oriented in anteversion or retroversion, as well as to determine any existing varus–valgus malalignment of the femoral stem. The “optimal” window of abduction and anteversion angles was considered to be 30°–45° and 5°–25°, respectively. These parameters were selected based on the work outlined in the publication on malpositioning by Callanan et al.

Comparative statistics were run between the morbidly obese and study control groups. Correlations between cup position measurements and clinical/demographic variables, with three or more categories, were assessed using the Kruskal–Wallis analysis of variance. Variables with two categories were assessed using a univariate binary logistical regression. Separate analyses were performed to assess each variable’s correlation relationship with the combined abduction and version window, cups abduced greater than 45°, cups abducted less than 30°, cups antverted greater than 25°, and cups antverted less than 5°. Primary diagnosis was assessed in four categories: osteoarthritis (OA), avascular necrosis/fracture (AVN), congenital/developmental dysplasia, and other, which encompassed all remaining diagnoses. Age at surgery was assessed in six categories: <40 years, 40–50 years, 50–60 years, 60–70 years, 70–80 years, and >80 years. Surgical approach was assessed in four categories: anterolateral, posterolateral, direct lateral, and minimally invasive (MIS). Forty-three patients (9.5%) did not have surgical approach data and were thus excluded from this analysis.

All variables exhibiting a significant correlation with cup position were combined in a stepwise multivariate binary logistic regression model to assess the significance of BMI on acetabular cup position while simultaneously controlling for the confounding effect of other variables. Correlations with P values of <0.05 were considered significant. Odds ratios were calculated for each individual variable to evaluate the probability of influence in malpositioning. Statistical analysis was performed using SPSS software (IBM, Chicago, IL).

Results

Group Profiles

A total of 211 patients (220 hips) with BMI \(\geq 35\) (morbidly obese) and 211 patients (220 hips) with BMI in the normal range (control) were queried in a hospital-based arthroplasty registry and matched for gender, age, and primary diagnosis. Of the full cohort of 422 patients, 226 were female and 196 were male. The mean age at surgery was 65 (range 21–92). Four-hundred twenty patients received total hip replacement with 26 mm, 28 mm, 32 mm, 36 mm, 38 mm or 40 mm cobalt-chrome femoral heads paired with 10 Mrad-irradiated and melted highly cross-linked polyethylene (HXLPE) liners, while two patients received hip resurfacing with 46- and 50-mm femoral heads.

Descriptive Statistics

Of the 440 hips, 310 (70.5%) had a primary diagnosis of osteoarthritis, 82 (18.6%) had a primary diagnosis of congenital or developmental dysplasia, 30 (6.8%) had a primary diagnosis of avascular necrosis (AVN) or fracture, and 18 (4.1%) had miscellaneous primary diagnoses (tumor, systemic lupus erythematosus (SLE), too far advanced). Three-hundred sixty-six (83.8%) of the cases were performed by high-volume surgeons (surgeons who performed, in excess, of 100 THAs per year) while 74 (16.8%) were performed by low-volume surgeons. One hundred sixty-five cups (37.5%) were press-fit, 271 cups (61.6%) were press-fit with screw fixation, and 4 cups (0.9%) were cemented. Of the 440 hips, 245 cases (55.7%) were performed with posterolateral approach, 108 (24.5%) with anterolateral approach, 30 (6.8%) with MIS approach, and 14 (3.2%) with direct lateral approach, and 43 (9.8%) had no available approach data. These 43 cases were excluded from analyses involving this variable.

In the morbidly obese group, the mean BMI was 38.7 (range 35.0–54.3 kg/m²), compared to 23.1 in the control group (range 18.9–24.9 kg/m²). The mean cup abduction angle in the morbidly obese group was 43.4° (range 27.4°–63.6°) (Fig. 1) while the mean version angle was 11.9° (range −12.9° to 37.0°), compared to 43.1° abduction (range 20.6°–66.5°) and 15.2° version (range 0.0°–43.0°) in the control group. One hundred thirty-five (61.4%) cups in the morbidly obese group fell within the optimal abduction range, while 160 cups (72.7%) fell within the optimal version range, compared to 132 (60%) cups and 179 (81.4%) cups respectively in the control group. One hundred three (46.8%) cups fell within the optimal combined abduction and version window for the morbidly obese group compared to 105 (47.7%) cups in the control group (Fig. 2).

Group Comparison

Clinical and demographic data were stratified and analyzed using either the Kruskal–Wallis test (for variables that could be stratified by three or more groups, i.e. “surgical approach” as anterolateral, posterolateral, direct lateral, and minimally invasive (MIS)) or a univariate logistical regression (for variables that could be stratified
The morbidly obese patients in this cohort did not show any mean significant difference from the control group when evaluating positioning for “optimal” abduction, positioning outside of the designated “safe zone” (30°–45° abduction, and 5°–25° anteversion), or in varus–valgus alignment of the femoral stem. However, there was a trend toward underanteversion of the acetabular cup when evaluating that variable exclusively. Also, when performing a multivariate analysis, there was a significant trend toward combined underanteversion/overabduction in the morbidly obese cohort. This—along with the 95% confidence suggested by the odds ratios—reveals that morbidly obese patients can be correlated with very specific, unfavorable orientations of acetabular cup implantation. Furthermore, morbid obesity was the single most significant variable leading to malpositioning of the acetabular cup out of all other variables considered, including surgical approach, surgeon volume, and fixation method. While the publication from Callanan et al identified obesity as a risk factor for malpositioning, this evaluation is the first of its kind to examine the implications of cup positioning in the morbidly obese patient, specifically.

This study found a correlation between specific aspects of acetabular cup malpositioning and the morbidly obese patient. There are two primary factors that may explain the trend in our data. First, operating on a patient with a large BMI makes it difficult to identify bony landmarks through the excess adipose tissue. This could potentially lead to underanteversion of the acetabular cup due to poor exposure while operating within the confines of a deep surgical wound. Second, standard surgical instrumentation is not designed for the morbidly obese patient. As the depth of the surgical wound increases, the length of the standard surgical tool may become inadequate.

This study had limitations. First, we were not able to correlate patients in our cohort to their respective clinical outcomes. However, we are conducting an ongoing prospective multicentric study wherein we are following primary total hip arthroplasty patients for 10 years. Second, there are many different definitions of “safe zone.” We acknowledge these differences, however, there is no current consensus in the orthopedic literature. Thus, we elected to define our window based on the publication from Callanan et al. for comparison between the two groups. Third, we did not evaluate our cohorts with respect to different bearing surfaces, as the majority of the patients received a metal-on-polyethylene system. As more evidence surfaces to suggest the detrimental effects of hard-on-hard bearings, it will become important to understand the loading and wear of these components in the morbidly obese.

As the epidemic of obesity continues, and greater numbers of the morbidly obese population require THA, surgeons can expect to see an increasing number of these patients in their clinics. This study is the first of its kind to focus specifically on cup positioning in the morbidly obese patient, which demonstrated a trend toward underanteversion alone, as well as a combined underanteversion/overabduction when evaluating multiple variables. Due to the challenges associated with performing a total hip arthroplasty procedure on a morbidly obese patient, it is critical to understand the risk factors that may contribute to cup malpositioning. Further studies will be required to fully understand the risks associated with component positioning in the morbidly obese patient during total hip arthroplasty.

**Logistic Regression for Multiple Variables**

A stepwise multivariate binary logistic regression analysis using BMI, surgical approach, surgeon volume, and acetabular fixation method as input variables was determined to be the final best-fit model. The binary model revealed a significant effect of BMI on underanteverted cups (<5°, P < 0.0005), with concurrent significance observed with surgical approach and acetabular fixation method (P = 0.04, P = 0.01). Although the latter variables offer the possibility of a confounding effect on underanteverted cups, BMI was the most highly significant variable, and demonstrated the same level of significance under all other combinations of the binary model (P = 0.0005). BMI was also observed to be the sole significant factor on cups that were simultaneously under anteverted and over abducted (<5°, >45°, P = 0.02). The odds ratio for BMI and underanteversion was 3.496 with a positive coefficient (95% CI). This suggests a high probability of underanteversion associated with the morbidly obese group in comparison to surgical approach, surgeon volume, and fixation method (2.000, 0.612, 2.827). The odds ratio for BMI and combined underanteversion/overabduction similarly demonstrated a high odds ratio of 3.405.

**Discussion**

The obesity epidemic in the United States will continue to pose a challenge for healthcare providers, regardless of specialty [13]. However, treating morbidly obese patients in orthopedics presents a unique obstacle in arthroplasty. As malpositioning of the acetabular cup has been shown to be associated with poor clinical outcomes, including dislocation, it is critical to evaluate the practice of accurate component positioning in the morbidly obese [16].

**References**