Accuracy of Acetabular Component Position in Hip Arthroplasty

Robert L. Barrack, MD, Jeffrey A. Krempec, MD, John C. Clohisy, MD, Douglas J. McDonald, MD, William M. Ricci, MD, Erin L. Ruh, MS, and Ryan M. Nunley, MD

Investigation performed at the Department of Orthopaedic Surgery, Washington University School of Medicine, St. Louis, Missouri

Background: Acetabular component malposition is linked to higher bearing surface wear and component instability. Outcomes following total hip arthroplasty and surface replacement arthroplasty depend on multiple surgeon and patient-dependent factors. The purpose of this study was to examine the frequency in which acetabular components are placed within a predetermined target range.

Methods: We evaluated postoperative anteroposterior pelvic radiographs for every consecutive primary total hip arthroplasty and surface replacement arthroplasty completed from 2004 to 2009 at a single institution. Acetabular component abduction and anteversion angles were determined using Martell Hip Analysis Suite software. We defined target ranges for abduction and anteversion for both total hip arthroplasty (30° to 55° and 5° to 35°, respectively) and surface replacement arthroplasty (30° to 50° and 5° to 25°, respectively). Surgeon and patient-related factors were analyzed for risk associated with placing the acetabular component outside the target range.

Results: Of the 1549 total hip arthroplasties, 1435 components (93%) met our abduction target, 1472 (95%) met our anteversion target, and 1363 (88%) simultaneously met both targets. Of the 263 surface replacement arthroplasties, 233 components (89%) met our abduction target, 247 (94%) met our anteversion target, and 220 (84%) simultaneously met both targets. When previously published target ranges of abduction (30° to 45°) and anteversion (5° to 25°) angles were used, only 665 total hip replacements (43%) met the abduction target, 1325 (86%) met the anteversion target, and 584 (38%) simultaneously met both targets. Of the surface replacement arthroplasties, 181 (69%) met the abduction target, 247 (94%) met the anteversion target, and 172 (65%) simultaneously met both targets. Low-volume surgeons were 2.16 times more likely to miss target component position compared with high-volume surgeons ($p = 0.002$). The odds of missing the target increased by ≥0.2 for every 5 kg/m^2 increase in body mass index. Minimally invasive approaches, diagnosis, years of surgical experience, femoral head size, and age of the patient did not affect component position.

Conclusions: Increased odds of component malposition were found with lower-volume surgeons and higher body mass index. No other variables had a significant effect on component placement.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Outcomes following total hip arthroplasty and hip surface replacement arthroplasty depend on multiple surgeon and patient-dependent factors. These factors may influence pain relief, hip motion, prevalence of instability, and lifespan of the components. Surgeon-controlled variables that may influence outcome are surgical approach[1-4], surgeon volume[5,6], component type[7,8], component placement[9], and component fixation[10].

The orientation of the acetabular component in total hip arthroplasty and surface replacement arthroplasty may play a role in multiple facets of the overall outcome. Lewinnek et al.[11] defined a so-called safe-zone for acetabular components as a mean (and standard deviation) of 15° ± 10° of anteversion and 40° ± 10° of abduction, and although this was a limited study of 122 patients with implants that are currently not commonly

Disclosure: None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. One or more of the authors, or his or her institution, has had a financial relationship, in the thirty-six months prior to submission of this work, with an entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. No author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete **Disclosures of Potential Conflicts of Interest** submitted by authors are always provided with the online version of the article.

TABLE I Number of Acetabular Components Positioned within Defined Target Ranges in 1549 Total Hip Arthroplasties

	Abduction (Inclination)*		Anteversion*		
	Range	Components within Range	Range	Components within Range	Components within Both Ranges
Target range					
Current study	30°-55°	1435 (92.6%)	5°-35°	1472 (95.0%)	1363 (88.0%)
Previous study[31]	30°-45°	665 (42.9%)	5°-25°	1325 (85.5%)	584 (37.7%)
Actual range	25°-81°		0°-43°		
Mean ± 1 SD†	39.8°-52.9°	1091 (70.4%)	9.2°-23.9°	1080 (69.7%)	773 (49.9%)
Mean ± 2 SD†	33.2°-59.5°	1479 (95.5%)	1.9°-31.2°	1486 (95.9%)	1424 (91.9%)

*The mean abduction angle (and standard deviation) for all 1549 acetabular components was 46.3° ± 6.6°, and the mean anteversion was 16.5° ± 7.3°. †The mean of the target range for the current study. SD = standard deviation.

used in the United States, these goals have been utilized widely for several decades. Acetabular component malposition is a factor that contributes to increased dislocation rates, limb-length discrepancy, component impingement, bearing surface wear, pelvic osteolysis, and earlier revisions in the long term[9,11,12].

Dislocation after primary total hip arthroplasty affects between 0.5% and 5%[13,14] of patients. Acetabular component orientations that fall within target ranges have a much lower prevalence of all types of dislocations, while components that fall outside the safe zone are associated with higher rates of dislocation and recurrent dislocations[11,15-19]. Many studies have targeted the safe zone identified by Lewinnek et al.[11], but ideal component positions have ultimately ranged between 5° and 40° for anteversion and between 30° and 55° for abduction[15-20]. Components with high degrees of anteversion correlate with an increased prevalence of anterior dislocation, while those with a high degree of retroversion correlate with an increased risk of posterior dislocation[7,11].

The advent and popularity of alternative bearing surfaces has been accompanied by new complications such as polyethylene liner fracture, acoustic phenomenon, metal sensitivity, and pseudotumors. Acetabular component position has been implicated as one of several causative factors for each of these complications[21-25]. Higher wear rates in both conventional[26] and hard-on-hard[27] bearings are seen with higher abduction angles. Abduction angles of >55° have been implicated in increased wear and edge loading[28], as well as increased serum metal ion levels[27]. Increased abduction and anteversion angles have repeatedly correlated with higher serum metal ion levels following metal-on-metal hip arthroplasty[25,27,29,30]. It seems component position is more important in these hard-on-hard bearings with less margin for error.

With such emphasis on acetabular component position, minimizing risk factors for malposition is desirable. A recent study at a large academic center with diverse faculty determined factors linked to acetabular component malposition during primary and revision total hip arthroplasty[31]. This group reported an independently increased risk of acetabular component malposition for surgeons with a low volume, with a minimally invasive approach, and in patients with a body mass index (BMI) of >30 kg/m^2. Target angle ranges were set at 30° to 45° for abduction and 5° to 25° for anteversion on the basis of surgeon consensus and standards from previous studies. These included both hard-on-soft and hard-on-hard bearings, but were not separated in the analysis. Other studies with

TABLE II Number of Acetabular Components Positioned within Defined Target Ranges in 263 Surface Replacement Arthroplasties

	Abduction (Inclination)*		Anteversion*		
	Range	Components within Range	Range	Components Within Range	Components within Both Ranges
Target range					
Current study	30°-50°	233 (88.6%)	5°-25°	247 (93.9%)	220 (83.7%)
Previous study[31]	30°-45°	181 (68.8%)	5°-25°	247 (93.9%)	172 (65.4%)
Actual range	28°-71°		1°-31°		
Mean ± 1 SD†	36.8°-49.1°	191 (72.6%)	7.4°-18.4°	172 (65.4%)	127 (48.3%)
Mean ± 2 SD†	30.7°-55.2°	253 (96.2%)	1.9°-23.9°	254 (96.6%)	245 (93.2%)

*The mean abduction angle (and standard deviation) for all 263 surface replacement arthroplasties was 43.0° ± 6.1°, and the mean anteversion was 12.9° ± 5.5°. †The mean of the target range for the current study. SD = standard deviation.

TABLE III Univariate Analysis of Factors Tested for Component Position within Defined Target Ranges for Total Hip Arthroplasty

	No. of Total Hip Arthroplasties			
Factor	Total	Within Both Ranges*	Outside Range	P Value
	1549	1363 (88%)	186 (12%)	
Sex				0.449
Male	701	612 (87%)	89 (13%)	
Female	848	751 (89%)	97 (11%)	
Age groups *(yr)*				0.519
<50	372	333 (90%)	39 (10%)	
50-70	860	755 (88%)	105 (12%)	
>70	317	275 (87%)	42 (13%)	
Body mass index *(kg/m²)*				0.020
≤24.99	350	321 (92%)	29 (8%)	
25-29.99	523	463 (89%)	60 (11%)	
30-34.99	388	339 (87%)	49 (13%)	
35-39.99	177	150 (85%)	27 (15%)	
≥40	111	90 (81%)	21 (19%)	
Head size *(mm)*				0.392
<32	209	178 (85%)	31 (15%)	
32	767	677 (88%)	90 (12%)	
>32	573	508 (89%)	65 (11%)	
Approach				<0.001
Posterolateral	898	791 (88%)	107 (12%)	
Minimal incision posterolateral	497	451 (91%)	46 (9%)	
Anterolateral	154	121 (79%)	33 (21%)	
Diagnosis				0.502
Osteoarthritis	1132	999 (88%)	133 (12%)	
Osteonecrosis	203	176 (87%)	27 (13%)	
Dysplasia	85	78 (92%)	7 (8%)	
Fracture	42	36 (86%)	6 (14%)	
Rheumatoid arthritis	31	28 (90%)	3 (10%)	
Tumor related	25	19 (76%)	6 (24%)	
Other	31	27 (87%)	4 (13%)	
Surgeon volume				0.001
High (≥50 cases/yr)	1292	1152 (89%)	140 (11%)	
Low (<50 cases/yr)	257	211 (82%)	46 (18%)	
Surgeon experience				0.184
High (≥5 yr)	1324	1171 (88%)	153 (12%)	
Low (<5 yr)	225	192 (85%)	33 (15%)	

*The abduction range was 30° to 55°, and the anteversion range was 5° to 35°.

smaller numbers have failed to show a link between surgeon experience[32] or BMI[33] and component position.

The purpose of this study was to examine the frequency in which acetabular components are placed within a determined target range. Furthermore, we examined surgeon and patient-related factors to determine their impact on component placement. Specifically, this study was designed to (1) determine the number of optimally positioned acetabular cups in a large sample of patients after primary total hip arthroplasty and surface replacement arthroplasty on the basis of various patient-related and surgical factors using a different target range than previously reported and (2) to determine the independent predictors of malpositioned components and to use those predictors to calculate odds ratios for increased risk of malpositioning.

Materials and Methods

Using our prospectively constructed database, we identified 1911 patients (2137 hips) who underwent primary total hip arthroplasty or surface

TABLE IV Univariate Analysis of Factors Tested for Component Position within Defined Target Ranges for Surface Replacement Arthroplasties

	No. of Surface Replacement Arthroplasties			
Factor	Total	Within Both Ranges*	Outside Range	P Value
	263	220 (84%)	43 (16%)	
Sex				0.360
Male	220	182 (83%)	38 (17%)	
Female	43	38 (88%)	5 (12%)	
Age groups *(yr)*				0.903
<50	108	90 (83%)	18 (17%)	
50-70	154	129 (84%)	25 (16%)	
>70	1	1	0	
Body mass index *(kg/m²)*				0.016
≤24.99	60	58 (97%)	2 (3%)	
25-29.99	137	109 (80%)	28 (20%)	
30-34.99	58	45 (78%)	13 (22%)	
35-39.99	7	7	0	
≥40	1	1	0	
Head size (all >32 mm)	—	—	—	—
Approach (all posterolateral)	—	—	—	—
Diagnosis				0.193
Osteoarthritis	249	208 (84%)	41 (16%)	
Osteonecrosis	9	8 (89%)	1 (11%)	
Dysplasia	3	3	0	
Rheumatoid arthritis	1	0	1	
Other	1	1	0	
Surgeon volume (all high)	—	—	—	—
Surgeon experience				0.174
High (≥5 yr)	245	207 (84%)	38 (16%)	
Low (<5 yr)	18	13 (72%)	5 (28%)	

*The abduction range was 30° to 50°, and the anteversion range was 5° to 25°.

replacement arthroplasty from January 2004 through December 2009. The database was used to obtain information from each patient including laterality of the operatively treated hip; performing surgeon; age, sex, height, weight, and BMI of the patient; femoral head size utilized; acetabular cup outer diameter; surgical approach; and preoperative diagnosis. Patients were required to have a postoperative digital anteroposterior pelvic radiograph of acceptable quality including pelvic tilt, rotation, and leg position, according to criteria previously described by Callanan et al.[31]. Cross-table radiographs confirmed whether the component was anteverted or retroverted. Hips without adequate radiographs were excluded. This study was approved by the institutional review board.

Of the 1911 patients (2137 hips), 233 patients underwent either simultaneous or staged bilateral total hip arthroplasty or surface replacement arthroplasty. The second hip from these patients was excluded to avoid surgeon bias from the result of the first hip. Additionally, eighty-four hips were excluded because of a lack of acceptable radiographs and eight hips with a two-incision surgical approach were excluded because of a low sample size. From the remaining 1812 hips, 1549 total hip replacements and 263 surface replacements were analyzed.

The anteroposterior pelvic radiograph was measured using HAS software (version 8.0.1.7; Martell Hip Analysis Suite, Chicago, Illinois) to calculate the cup inclination and version angles. The reliability of this software has been previously demonstrated[31]. All radiographs were interpreted by a single author.

For the statistical analysis, we defined target ranges for abduction and anteversion for both total hip arthroplasty (30° to 55° and 5° to 35°, respectively) and for surface replacement (30° to 50°and 5° to 25°, respectively). These target ranges were determined on the basis of surgeon consensus of their goals for component placement during surgery. Eight variables were analyzed for correlation to acetabular component positioning. BMI was grouped by the World Health Organization classification, and the first two categories were combined with ≤24.99 kg/m² as underweight or normal weight. With 25 to 29.99 kg/m² classified as overweight, we then classified the obese in three categories: 30 to 34.99 kg/m², 35 to 39.99 kg/m², and ≥40 kg/m². For descriptive purposes, ages at the time of surgery were divided into three groups: less than fifty years, fifty to seventy years, and older than seventy years. Femoral head size was categorized as <32 mm, 32 mm, and >32 mm. Three surgical approach categories were used: posterolateral, minimal incision posterolateral, and anterolateral. Diagnosis was divided into seven groups: osteoarthritis, osteonecrosis, developmental dysplasia, fracture, rheumatoid arthritis, tumor-related, and other (Legg-Calvé Perthes disease, slipped capital femoral epiphysis, posttraumatic arthritis, ankylosing spondylitis, psoriatic arthritis, and septic arthritis). Surgeon volume was divided arbitrarily into those performing fewer than fifty hip replacements per year or those performing fifty or more per year. The high-volume group contributed 1292 total hip arthroplasties and 263 surface replacements (86%), while the low-volume group contributed 257 total

TABLE V Multivariate Analysis of Risk Factors for Component Position Outside Defined Target Ranges for Total Hip Arthroplasty*

Factor	Reference Category	Odds Ratio (95% Confidence Interval)	P Value
Body mass index *(kg/m²)*			0.04
25-29.99	<24.99	1.42 (0.88-2.27)	0.15
30-34.99	<24.99	1.62 (0.99-2.64)	0.05
35-39.99	<24.99	1.91 (1.08-3.39)	0.03
≥40	<24.99	2.57 (1.37-4.81)	0.003
Surgeon volume	High	2.16 (1.33-3.51)	0.002
Approach			<0.001
Minimally invasive	Posterolateral	0.98 (0.66-1.45)	0.91
Anterolateral	Posterolateral	5.05 (2.49-10.24)	<0.001
Interaction between approach and surgeon volume			0.001
Minimally invasive and low volume	Posterolateral and high volume	0.00 (0.00-0.00)	1.00
Anterolateral and low volume	Posterolateral and high volume	0.16 (0.06-0.41)	0.001

*The abduction range was 30° to 55°, and the anteversion range was 5° to 35°.

hip arthroplasties (14%). Surgeon experience was divided into two groups: high-experience surgeons were past their fifth year of practice, while low-experience surgeons were within their first five years of practice.

Each hip was examined and placed into one of two groups. One group consisted of components that met both the abduction and anteversion targets. Malpositioned components did not meet one or both targets. The target ranges established for this study were also compared with target ranges previously established in the literature[31] for abduction (30° to 45°) and anteversion (5° to 25°). We examined the percentage of hips falling within one and two standard deviations of the mean for abduction and anteversion. Each patient and surgeon variable was analyzed using univariate analysis for rates of correct component position. From there, surgeon and patient-related factors for total hip arthroplasty were analyzed for significance through multivariate logistic regression to determine whether there was an impact on component placement. The final model included BMI, surgical approach, surgeon volume, and the interaction between surgeon volume and surgical approach. Only one variable (BMI) was found to be significant for surface replacement arthroplasty and was analyzed using the chi-square test.

Source of Funding

No funding was received in support of this study.

Results

For the 1549 total hip arthroplasties, the mean abduction angle was 46.3° and the mean anteversion angle was 16.5°,

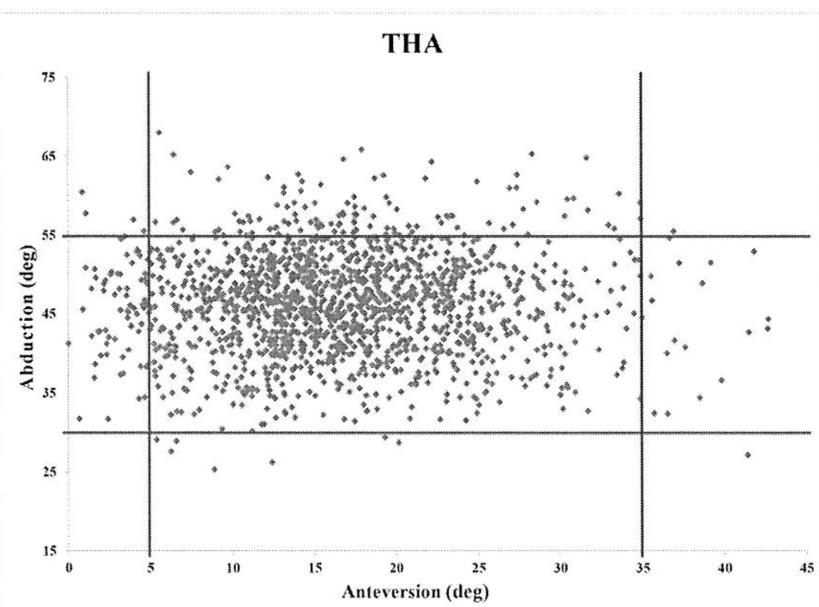

Fig. 1
Scatterplot depicting the number of total hip arthroplasties (THA) within defined target ranges, indicated by the red lines, for both abduction (30° to 55°) and anteversion (5° to 35°).

TABLE VI Odds Ratios for Component Placement in Surface Replacement Arthroplasty

Factor	Reference Category	Odds Ratio (95% Confidence Interval)	P Value
Body mass index *(kg/m²)*			0.102
25-29.99	<24.99	7.45 (1.71-32.38)	0.007
30-34.99	<24.99	8.38 (1.80-39.03)	0.007
35-39.99	<24.99	0.00 (0.00-0.00)	1.00
≥40	<24.99	0.00 (0.00-0.00)	1.00

while for the 263 surface replacement arthroplasties, the mean abduction angle was 43.0° and the mean anteversion angle was 12.9°. Overall, 1363 (88%) of the total hip arthroplasty components simultaneously met both our abduction and anteversion targets (Fig. 1 and Table I). Additionally, 50% of the total hip arthroplasty components were within one standard deviation of the mean for both target ranges, and 92% were within two standard deviations of both means. Of the surface replacement arthroplasties, 220 components (84%) met both our abduction and anteversion targets (Fig. 2 and Table II). The surface replacement components were within one standard deviation of both means 48% of the time and within two standard deviations 93% of the time. When a previously published range of abduction (30° to 45°) and anteversion (5° to 25°) angles was used[31], lower percentages fell within the target ranges. Only 584 (38%) of the total hip arthroplasties and 172 (65%) of the surface replacement arthroplasties simultaneously met both of these targets.

A summary of component placement for each of the variables analyzed in univariate analysis is shown in Tables III and IV for total hip arthroplasties and surface replacements, respectively. The multivariate analysis of risk factors for component placement outside target ranges for total hip arthroplasty is presented in Table V. Multivariate logistic regression analysis revealed that a BMI of ≥30, low-volume surgeons, and anterolateral approach had an impact on component positioning for total hip arthroplasties (Table V). The odds ratio for low-volume surgeons was 2.16 ($p = 0.002$) compared with that of high-volume surgeons for placing components outside target ranges. The odds of missing the target ranges increased by ≥0.2 for every 5 kg/m² increase in BMI. The odds of placing components outside target ranges was 5.05 times higher in patients who had an anterolateral approach compared with patients who had a posterolateral approach ($p < 0.001$), and the interaction between surgical approach and surgeon volume was significant ($p = 0.001$). Minimally invasive approaches did not have a significant effect on component placement. The odds ratios for the placement of surface replacement components were calculated using chi-square analysis (Table VI). The odds of cup malpositioning with surface replacement arthroplasty was 7.45 times higher in patients with a BMI of 25 to 29.99 kg/m² and 8.38 times higher in patients with a BMI of 30 to 34.99 kg/m² compared with patients with a BMI of <24.99 kg/m² ($p = 0.007$).

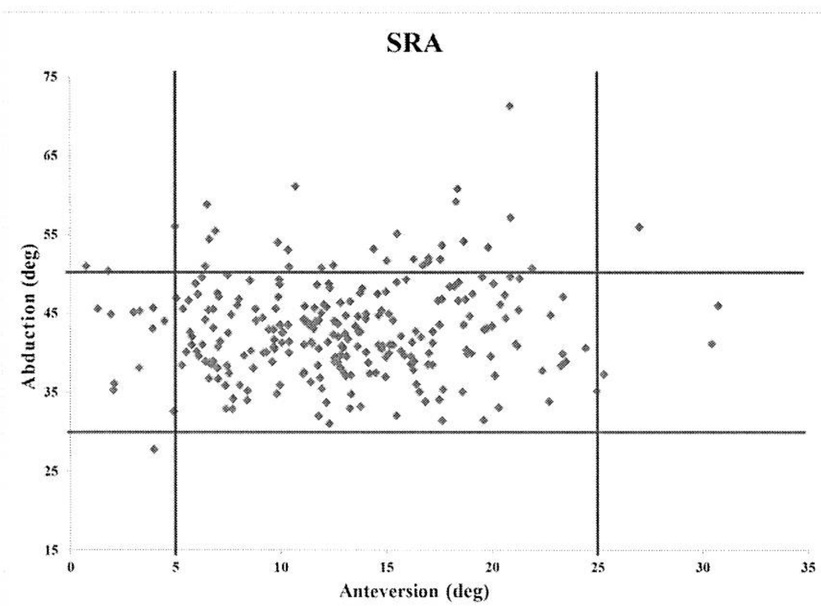

Fig. 2
Scatterplot depicting the number of surface replacement arthroplasties (SRA) within defined target ranges, indicated by the red lines, for both abduction (30° to 50°) and anteversion (5° to 25°).

Discussion

Acetabular component malposition is a factor that contributes to increased dislocation rates, limb-length discrepancy, component impingement, bearing surface wear, pelvic osteolysis, and revisions in the long term[9,11,12]. The popularity of alternative bearings has brought about new complications that may be perpetuated by component malposition, and hard-on-hard bearings are possibly more sensitive to malposition than hard-on-soft bearings[27,28]. We designed this study to examine our accuracy of placing the acetabular component within our defined goals of abduction and anteversion for both hard-on-soft and hard-on-hard bearings. Using the acetabular component position along with surgeon and patient-related variables, we determined independent risk factors for acetabular component malpositioning.

There is little literature regarding possible risk factors for the malpositioning of acetabular components. In the most comprehensive study to date, Callanan et al.[31] examined a large number of primary and revision total hip arthroplasties and surface replacement arthroplasties. This group evaluated a heterogeneous mix of patients and procedures in both the revision and primary setting using different abduction (30° to 45°) and anteversion angles (5° to 25°) than we used in the present study. They demonstrated that a minimally invasive approach, a low-volume surgeon, and patients with a BMI of >30 kg/m^2 were independent risk factors for malposition of the acetabular component, but did not distinguish between total hip arthroplasty and surface replacement arthroplasty or between hard-on-soft and hard-on-hard bearing surfaces. We chose to examine only primary total hip arthroplasty and surface replacement arthroplasty, noting that desired acetabular component position may differ in the revision setting with respect to bone loss, deformity, retained femoral component position, and bearing type. Additionally, we utilized different goals for our acetabular component position. Rather than exclusively using the literature for guidance retrospectively, the surgeons developed a prospective consensus of what their goals for implantation during surgery were. In this view, we had an optimal target range of angles representing "acceptable" and not necessarily "ideal." For example, the previous study[31] used a tighter range of abduction angles (30° to 45°). For total hip arthroplasty, our implantation goal was 45°, with a target range of 30° to 55°. We did not believe that our goal should be the upper limit of our target range with no margin for error with higher abduction angles. The same philosophy held true for anteversion angles in the total hip arthroplasty group. We recognized these target ranges were arbitrary so we also reported the percentage of cups falling within one and two standard deviations of the mean for abduction and anteversion. The target ranges that we chose closely approximated the ranges of values that were actually found in our cohort. "Perfect" acetabular component positioning is unlikely to always be achieved, but a surgeon should aim to place a majority of implants within an acceptable target range. Identifying an ideal range would allow surgeons to judge their own practices and try to improve their technique.

Despite the different ranges identified for this study, we too found low-volume surgeons and increased BMI to be risk factors for acetabular component malposition, similar to the findings of Callanan et al.[31]. The low-volume surgeon was 2.16 times more likely ($p = 0.002$) than the high-volume surgeon to have a malpositioned component. This supports the twofold risk determined by the previous group. Multiple studies have examined surgeon volume in relation to transfusion rates, readmission rates, length of hospital stay, dislocation, preoperative diagnosis, and other outcome measures[5,6,34,35]. In our analysis, we differentiated surgeon volume and experience as separate categories and, to our knowledge, this has not been reported previously. One smaller study found surgical experience not to be a risk factor for malpositioned components[32], while another found attending surgeons to be more accurate than residents[36]. Our analysis found no effect based on surgeon experience, with no difference between surgeons with high volume and low experience and surgeons with high volume and high experience. All of the low-volume surgeons in our present study were of high experience, indicating that consistent repetition over a short period of time may be more important than cumulative experience over a longer period of time.

We found an increased risk of missing the target with increasing BMI. While Callanan et al. reported a BMI of >30 as a 1.3-fold increase in relative risk, we found a more linear relationship. The risk of malposition increased by ≥0.2 for each 5 kg/m^2 increase in BMI throughout the range of BMI observed. Therefore, a patient with a BMI of 25 is at higher risk for malposition than a patient with a BMI of 20. This suggests a patient is at higher risk of malposition than another patient of smaller BMI.

The literature contains mixed results for this variable. Three studies indicated that BMI had no effect on acetabular component position[33,36,37], while another showed that obesity (defined in the study as a BMI of ≥25) had a significant effect ($p = 0.01$) on component position when utilizing imageless navigation for implant positioning[38]. All four studies were limited by small sample sizes (between sixty-nine and 323 patients).

The current study did not find an increased risk associated with a minimally invasive approach. Multiple studies have described the excellent, equivalent clinical and functional outcome of different minimally invasive approaches[39-43]. However, they did not analyze acetabular component position. Williams et al.[44] compared acetabular component position after sixty-seven minimally invasive, two-incision total hip arthroplasties and twenty-eight standard total hip arthroplasties. The average abduction and anteversion of the acetabular components did not differ between the two groups. Hart et al.[43] found no difference in acetabular abduction or anteversion angles after sixty minimally invasive posterolateral total hip arthroplasties compared with sixty standard posterolateral total hip arthroplasties. Two other studies corroborated the absence of increased risk associated with a minimally invasive approach for total hip arthroplasty and surface replacement arthroplasty[36,45]. Our study examined substantially more hips than all of those studies;

however, our results mirrored those previously described. This is in direct contrast to the only other large study, by Callanan et al.[31], which demonstrated a sixfold increase in risk of component malposition when a minimally invasive approach was used. In the present study, virtually all minimally invasive total hip arthroplasties (97%) were performed by two surgeons. The results, therefore, may be specific to the skill level of the surgeon, but it is clear that consistent positioning is attainable through a posterior minimally invasive approach.

Although the current study found an increased risk associated with an anterolateral approach, the majority of anterolateral approach procedures were conducted by low-volume surgeons. Therefore, it is unclear whether this risk is attributable to the surgeon or the approach.

The target ranges for abduction, anteversion, and both were achieved in 93%, 95%, and 88%, respectively, of the patients who had total hip arthroplasty, which is a high success rate. This means, however, that a substantial number of patients are outside this range. For this study group, this would mean that 114 patients missed the abduction target, seventy-seven missed the anteversion target, and 186 missed both targets. If the abduction target is decreased to 30° to 50° and the anteversion target to 5° to 30°, the numbers out of range increase dramatically as 411 patients missed the abduction target, 115 missed the anteversion target, and 493 missed both targets. This emphasizes the importance of surgical techniques and devices being relatively forgiving with regard to component placement. Whether cup positioning outside our target range is associated with poor clinical outcomes remains to be determined. Until such time as there is a major advance that leads to virtual elimination of outliers for acetabular component positioning, the use of components or bearing surfaces that have a high risk of major complications when positioned outside a defined range of acetabular component position should be undertaken with caution. ■

NOTE: The authors thank Humaa Nyazee, MPH, for her assistance with the statistical analysis for this manuscript.

Robert L. Barrack, MD
John C. Clohisy, MD
Douglas J. McDonald, MD
William M. Ricci, MD
Erin L. Ruh, MS
Ryan M. Nunley, MD
Department of Orthopaedic Surgery,
Washington University School of Medicine,
660 South Euclid Avenue,
Campus Box 8233,
St. Louis, MO 63110.
E-mail address for R.L. Barrack: barrackr@wustl.edu

Jeffrey A. Krempec, MD
Drisko, Fee & Parkins,
2790 Clay Edwards Drive, Suite 600,
North Kansas City, MO 64116

References

1. Restrepo C, Parvizi J, Pour AE, Hozack WJ. Prospective randomized study of two surgical approaches for total hip arthroplasty. J Arthroplasty. 2010 Aug;25(5):671-9:e1. Epub 2010 Apr 08.

2. Arthursson AJ, Furnes O, Espehaug B, Havelin LI, Söreide JA. Prosthesis survival after total hip arthroplasty—does surgical approach matter? Analysis of 19,304 Charnley and 6,002 Exeter primary total hip arthroplasties reported to the Norwegian Arthroplasty Register. Acta Orthop. 2007 Dec;78(6):719-29.

3. Enocson ATJ, Tidermark J, Tornkvist H, Lapidus LJ. Dislocation of hemiarthroplasty after femoral neck fracture: better outcome after the anterolateral approach in a prospective cohort study on 739 consecutive hips. Acta Orthop. 2008 Apr;79(2):211-7.

4. Mallory TH, Lombardi AV Jr, Fada RA, Herrington SM, Eberle RW. Dislocation after total hip arthroplasty using the anterolateral abductor split approach. Clin Orthop Relat Res. 1999 Jan;(358):166-72.

5. Ames JB, Lurie JD, Tomek IM, Zhou W, Koval KJ. Does surgeon volume for total hip arthroplasty affect outcomes after hemiarthroplasty for femoral neck fracture? Am J Orthop (Belle Mead NJ). 2010 Aug;39(8):E84-9.

6. Bozic KJ, Maselli J, Pekow PS, Lindenauer PK, Vail TP, Auerbach AD. The influence of procedure volumes and standardization of care on quality and efficiency in total joint replacement surgery. J Bone Joint Surg Am. 2010 Nov 17;92(16):2643-52.

7. Kelley SS, Lachiewicz PF, Hickman JM, Paterno SM. Relationship of femoral head and acetabular size to the prevalence of dislocation. Clin Orthop Relat Res. 1998 Oct;(355):163-70.

8. Kluess D, Martin H, Mittelmeier W, Schmitz KP, Bader R. Influence of femoral head size on impingement, dislocation and stress distribution in total hip replacement. Med Eng Phys. 2007 May;29(4):465-71. Epub 2006 Aug 09.

9. Kennedy JG, Rogers WB, Soffe KE, Sullivan RJ, Griffen DG, Sheehan LJ. Effect of acetabular component orientation on recurrent dislocation, pelvic osteolysis, polyethylene wear, and component migration. J Arthroplasty. 1998 Aug;13(5):530-4.

10. Conroy JL, Whitehouse SL, Graves SE, Pratt NL, Ryan P, Crawford RW. Risk factors for revision for early dislocation in total hip arthroplasty. J Arthroplasty. 2008 Sep;23(6):867-72. Epub 2008 Mar 07.

11. Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg Am. 1978 Mar;60(2):217-20.

12. Parvizi J, Sharkey PF, Bissett GA, Rothman RH, Hozack WJ. Surgical treatment of limb-length discrepancy following total hip arthroplasty. J Bone Joint Surg Am. 2003 Dec;85(12):2310-7.

13. Woo RY, Morrey BF. Dislocations after total hip arthroplasty. J Bone Joint Surg Am. 1982 Dec;64(9):1295-306.

14. Kwon MS, Kuskowski M, Mulhall KJ, Macaulay W, Brown TE, Saleh KJ. Does surgical approach affect total hip arthroplasty dislocation rates? Clin Orthop Relat Res. 2006 Jun;447(447):34-8.

15. Ali Khan MA, Brakenbury PH, Reynolds IS. Dislocation following total hip replacement. J Bone Joint Surg Br. 1981;63(2):214-8.

16. Biedermann R, Tonin A, Krismer M, Rachbauer F, Eibl G, Stöckl B. Reducing the risk of dislocation after total hip arthroplasty: the effect of orientation of the acetabular component. J Bone Joint Surg Br. 2005 Jun;87(6):762-9.

17. Jolles BM, Zangger P, Leyvraz PF. Factors predisposing to dislocation after primary total hip arthroplasty: a multivariate analysis. J Arthroplasty. 2002 Apr;17(3):282-8.

18. McCollum DE, Gray WJ. Dislocation after total hip arthroplasty. Causes and prevention. Clin Orthop Relat Res. 1990 Dec;(261):159-70.

19. Widmer KH, Zurfluh B. Compliant positioning of total hip components for optimal range of motion. J Orthop Res. 2004 Jul;22(4):815-21.

20. D'Lima DD, Urquhart AG, Buehler KO, Walker RH, Colwell CW Jr. The effect of the orientation of the acetabular and femoral components on the range of motion of the hip at different head-neck ratios. J Bone Joint Surg Am. 2000 Mar;82(3):315-21.

21. Blumenfeld TJ, McKellop HA, Schmalzried TP, Billi F. Fracture of a cross-linked polyethylene liner: a multifactorial issue. J Arthroplasty. 2011 Jun;26(4):e5-8. Epub 2010 Sep 18.

22. Halley D, Glassman A, Crowninshield RD. Recurrent dislocation after revision total hip replacement with a large prosthetic femoral head. A case report. J Bone Joint Surg Am. 2004 Apr;86(4):827-30.

23. Sexton SA, Yeung E, Jackson MP, Rajaratnam S, Martell JM, Walter WL, Zicat BA, Walter WK. The role of patient factors and implant position in squeaking of ceramic-on-ceramic total hip replacements. J Bone Joint Surg Br. 2011 Apr;93(4):439-42.

24. Brooks P. Component malposition in hip resurfacing. Orthopedics. 2010 Sep;33(9):646. Epub 2010 Sep 07.

25. Langton DJ, Jameson SS, Joyce TJ, Webb J, Nargol AVF. The effect of component size and orientation on the concentrations of metal ions after resurfacing arthroplasty of the hip. J Bone Joint Surg Br. 2008 Sep;90(9):1143-51.

26. Gallo J, Havranek V, Zapletalova J. Risk factors for accelerated polyethylene wear and osteolysis in ABG I total hip arthroplasty. Int Orthop. 2010 Feb;34(1): 19-26. Epub 2009 Feb 13.

27. De Haan R, Pattyn C, Gill HS, Murray DW, Campbell PA, De Smet K. Correlation between inclination of the acetabular component and metal ion levels in metal-on-metal hip resurfacing replacement. J Bone Joint Surg Br. 2008 Oct;90(10): 1291-7.

28. Leslie IJ, Williams S, Isaac G, Ingham E, Fisher J. High cup angle and micro-separation increase the wear of hip surface replacements. Clin Orthop Relat Res. 2009 Sep;467(9):2259-65. Epub 2009 Apr 11.

29. Langton DJ, Sprowson AP, Mahadeva D, Bhatnagar S, Holland JP, Nargol AV. Cup anteversion in hip resurfacing: validation of EBRA and the presentation of a simple clinical grading system. J Arthroplasty. 2010 Jun;25(4):607-13. Epub 2009 Dec 21.

30. Walter LR, Marel E, Harbury R, Wearne J. Distribution of chromium and cobalt ions in various blood fractions after resurfacing hip arthroplasty. J Arthroplasty. 2008 Sep;23(6):814-21. Epub 2008 Jan 22.

31. Callanan MC, Jarrett B, Bragdon CR, Zurakowski D, Rubash HE, Freiberg AA, Malchau H. The John Charnley Award: risk factors for cup malpositioning: quality improvement through a joint registry at a tertiary hospital. Clin Orthop Relat Res. 2011 Feb;469(2):319-29.

32. Reize P, Geiger EV, Suckel A, Rudert M, Wülker N. Influence of surgical experience on accuracy of acetabular cup positioning in total hip arthroplasty. Am J Orthop (Belle Mead NJ). 2008 Jul;37(7):360-3.

33. Todkar M. Obesity does not necessarily affect the accuracy of acetabular cup implantation in total hip replacement. Acta Orthop Belg. 2008 Apr;74(2):206-9.

34. Baker P, Dowen D, McMurtry I. The effect of surgeon volume on the need for transfusion following primary unilateral hip and knee arthroplasty. Surgeon. 2011 Feb;9(1):13-7. Epub 2010 Oct 08.

35. Malkani AL, Ong KL, Lau E, Kurtz SM, Justice BJ, Manley MT. Early- and late-term dislocation risk after primary hip arthroplasty in the Medicare population. J Arthroplasty. 2010 Sep;25(6)(Suppl):21-5. Epub 2010 Jun 11.

36. Bosker BH, Verheyen CC, Horstmann WG, Tulp NJ. Poor accuracy of freehand cup positioning during total hip arthroplasty. Arch Orthop Trauma Surg. 2007 Jul;127(5):375-9. Epub 2007 Feb 13.

37. Pirard E, De Lint JA. Anteversion of the acetabular component in obese patients. Hip Int. 2007 Apr-Jun;17(2):99-103.

38. Tsukada S, Wakui M. Decreased accuracy of acetabular cup placement for imageless navigation in obese patients. J Orthop Sci. 2010 Nov;15(6):758-63. Epub 2010 Nov 30.

39. Gerdesmeyer L, Gollwitzer H, Diehl P, Buttgereit B, Rudert M. The minimally invasive anterolateral approach combined with hip onlay resurfacing. Oper Orthop Traumatol. 2009 Mar;21(1):65-76.

40. Roth A, Venbrocks RA. Total hip replacement through a minimally invasive, anterolateral approach with the patient supine. Oper Orthop Traumatol. 2007 Dec;19(5-6):442-57.

41. Oinuma K, Eingartner C, Saito Y, Shiratsuchi H. Total hip arthroplasty by a minimally invasive, direct anterior approach. Oper Orthop Traumatol. 2007 Aug; 19(3):310-26.

42. Pflüger G, Junk-Jantsch S, Schöll V. Minimally invasive total hip replacement via the anterolateral approach in the supine position. Int Orthop. 2007 Aug;31(Suppl 1): S7-11.

43. Hart R, Stipcák V, Janecek M, Visna P. Component position following total hip arthroplasty through a miniinvasive posterolateral approach. Acta Orthop Belg. 2005 Feb;71(1):60-4.

44. Williams SL, Bachison C, Michelson JD, Manner PA. Component position in 2-incision minimally invasive total hip arthroplasty compared to standard total hip arthroplasty. J Arthroplasty. 2008 Feb;23(2):197-202.

45. Myers GJ, Morgan D, McBryde CW, O'Dwyer K. Does surgical approach influence component positioning with Birmingham Hip Resurfacing? Int Orthop. 2009 Feb; 33(1):59-63. Epub 2007 Oct 30.