HSSJ (2016) 12:240–244
DOI 10.1007/s11420-016-9488-6

HSS Journal®
The Musculoskeletal Journal of Hospital for Special Surgery

ORIGINAL ARTICLE

Higher Acetabular Anteversion in Direct Anterior Total Hip Arthroplasty: A Retrospective Case-Control Study

Antonia F. Chen, MD, MBA · Chi-Lung Chen, MD · Sara Low, MD · Wei-Ming Lin, MD · Karthikeyan Chinnakkannu, MBBS, MS · Fabio R. Orozco, MD · Alvin C. Ong, MD · Zachary D. Post, MD

Received: 10 November 2015/Accepted: 6 January 2016/Published online: 19 February 2016

Abstract *Background:* Surgical approach is known as a risk factor that influences cup malposition while performing total hip arthroplasty (THA). However, no study has been conducted comparing cup positioning between the supine direct anterior (DA) and supine direct lateral (DL) THA approaches. *Questions/Purposes:* (1) Is there a difference in acetabular cup positioning between supine DA and supine DL THA approaches? (2) Are there differences in complications based on acetabular cup positioning between the two approaches? *Methods:* From 2012 to 2014, 186 patients who underwent primary THAs using DA approach were matched with 186 patients using DL approach by body mass index, age, and gender. Cup anteversion and abduction angles were measured from standing anteroposterior pelvis radiographs by two blinded observers. The Lewinnek safe zone was used as the standard for cup positioning. Cup anteversion, abduction angles, and complications were recorded and compared. *Results:* Cup anteversion was on average 3° higher in the DA approach compared to the DL approach. The abduction angle for the DA approach was equivalent to the DL approach both averaging 46° to 47°. There were more DA hips outside of the safe zone (10%) for anteversion than DL (3%) hips. There were no differences in complications between DA and DL approaches. *Conclusion:* There is a tendency to antevert the acetabular cup when performing THAs using the DA approach, and one must be mindful of this when implanting the acetabular component.

Level of Evidence: Therapeutic study, Level III

This work was performed at The Rothman Institute.

Electronic supplementary material The online version of this article (doi:10.1007/s11420-016-9488-6) contains supplementary material, which is available to authorized users.

A. F. Chen, MD, MBA · S. Low, MD ·
K. Chinnakkannu, MBBS, MS · F. R. Orozco, MD ·
A. C. Ong, MD · Z. D. Post, MD
Rothman Institute, Thomas Jefferson University Hospital,
Philadelphia, PA, USA

C.-L. Chen, MD
Department of Orthopaedic Surgery
Chang Gung Memorial Hospital,
Chiayi, Taiwan

W.-M. Lin, MD
Department of Radiology
Chang Gung Memorial Hospital,
Chiayi, Taiwan

F. R. Orozco, MD · A. C. Ong, MD · Z. D. Post, MD (✉)
2500 English Creek Avenue, Building 1300,
Egg Harbor Township, NJ 08234, USA
e-mail: zacharypost@gmail.com

Keywords acetabular anteversion · direct anterior · direct lateral · total hip arthroplasty

Introduction

Total hip arthroplasty (THA) is one of the most commonly performed orthopedic surgeries in the USA [32]. Accurate component positioning is crucial for preventing mechanical problems after THA. In 1978, Lewinnek et al. introduced the "Lewinnek safe zone," which defined acetabular cup abduction of 40° ± 10° and anteversion of 15° ± 10° as the optimum range for cup positioning [12]. Many studies have supported positioning the acetabular component within the Lewinnek safe zone [1, 7, 30, 31], with an increased risk of hip dislocation reported as high as 6.9-fold greater if outside of this range [10]. Excessive anteversion has been shown to result in anterior dislocation, posterior impingement, and non-specific pain [4, 13, 20]. Retroversion can predispose patients to posterior dislocation [4]. Abduction exceeding the safe zone has also been associated with increased dislocations, anterior iliopsoas impingement, and reduced range of movement [4, 6, 20].

Although optimal cup position has been extensively described, there is limited literature on factors influencing acetabular cup positioning. The majority of studies in literature have focused on cup positioning in minimally invasive surgery (MIS) or computer-assisted navigation THA [16, 17, 21, 25, 26, 29]. One Japanese study by Takazawa et.al. investigated the difference in acetabular cup and femoral stem positioning comparing supine direct anterior (DA) and lateral decubitus direct lateral (DL) approaches, and found that cup anteversion was higher with the DA approach [28]. However, no studies have been conducted comparing supine DA to supine DL approaches with regards to acetabular cup positioning.

Therefore, the purposes of our study were to (1) determine if there is a difference in acetabular cup anteversion and abduction between DA and DL THAs and (2) evaluate if there were differences in complications based on acetabular cup positioning between the two approaches.

Patients and Methods

A retrospective case-control study was conducted at a single institution evaluating primary, unilateral THAs performed by two senior surgeons from 2012 to 2014 with institutional board review approval. Patients were excluded if their radiographs were inadequate for determining acetabular anteversion or if the size of the femoral head was unknown, since the radiographs of these patients could not be appropriately calibrated. There were 186 supine DA patients identified that were matched to 186 supine DL patients by body mass index (BMI), age, and gender.

Patients undergoing both surgical approaches received the same perioperative care. The components used in both approaches were similar. There were 24 metal on polyethylene (MOP) and 162 ceramic on polyethylene (COP) THAs performed through the DA approach, and there were 53 MOP and 133 COP THAs performed using the DL approach. The average cup size used in the DA approach (53.9 ± 3.7 mm) and the DL approach (54.7 ± 3.9 mm) were similar ($p = 0.05$), as well as the head size (DA 35.2 ± 2.3 mm, DL 34.7 ± 2.7 mm, $p = 0.06$). Every patient received prophylactic intravenous antibiotics, intravenous tranexamic acid, multimodal pain control, and venothromboembolism prophylaxis. All patients were weight bearing the day of surgery, and sequential compression devices were utilized while in the hospital. Patients received in-hospital physical therapy, and most patients were discharged home. Patients were followed 4 weeks, 6 months, and yearly postoperatively.

The average age of the DA group was 67.7 ± 9.8 years, and the average age of the DL group was 68.0 ± 10.8 years. The average BMI of the DA group was 30.2 ± 5.1 kg/m^2, and the average BMI of the DL group was 30.1 ± 5.2 kg/m^2. There were 89 females and 97 males in the DA group, and there were 94 females and 92 males in the DL group. There were 96 right THAs and 90 left THAs in the DA group, and there were 93 right THAs and 93 left THAs in the DL group. The average follow-up was 309.7 days. Table 1 lists the study demographics.

Acetabular anteversion was measured from standing postoperative anteroposterior (AP) pelvis radiographs using Martell Hip Analysis Suite 8.0.4.3 [8]. The ischial tuberosities, edge of the femoral head with a known size, inferior and superior apexes of the acetabular cup, and ellipse edge were identified (Fig. 1). Cup anteversion and abduction angles were measured by two independent and blinded observers. The Lewinnek safe zone for anteversion was defined as 5° < anteversion angle < 25°, and the safe zone for abduction was defined as 30° < abduction angle < 50°.

Complications were defined as those that required reoperation, including dislocation, component loosening, and infection. Infection was defined by the International Consensus Meeting definition of periprosthetic joint infection (PJI) [22].

Statistical analysis on continuous variables was performed using Student's *t* test, and categorical variables were analyzed using chi-squared tests. Statistical significance was set at $p < 0.05$. Intrarater reliability was measured with the intraclass correlation coefficient (ICC). All statistical analysis was performed with Predictive Analytics SoftWare Statistics Version 22.0 (SPSS, Chicago, IL).

Results

The abduction angle for the DA approach (mean 47.6° ± 7.5°) was equivalent to the DL approach (46.2° ± 10.9°, $p = 0.133$). On the other hand, cup anteversion was higher in the DA approach (18.1° ± 5.2°) compared to the DL approach (15.0° ± 4.9°, $p < 0.001$). There was good correlation between measurements, as the abduction angle ICC was 0.92 and the anteversion angle ICC was 0.84. There were more DA hips outside of the safe zone for anteversion. For DA anteversion, 2/186 (1.1%) were <5° and 16/186 (8.6%) were >25°. For DL anteversion, 4/186 (2.2%) were <5° and 2/186 (1.1%) were >25° (p = 0.01).

With regard to complications, there was one dislocation in the DA approach and no dislocations in the DL approach ($p = 0.32$). There were two PJIs in the DA group and no PJIs in the DL group ($p = 0.16$). There were five loose femoral stems in the DA group that required revision, and one loose femoral stem and one loose acetabular component in the DL group ($p = 0.25$).

Table 1 Demographics of the patient population

	Direct anterior	Direct lateral	*p* value
Age (years)	67.7 ± 9.8	68.0 ± 10.8	0.76
Gender	89 females 97 males	94 females 92 males	0.60
Body mass index (kg/m$^{2)}$	30.2 ± 5.1	30.1 ± 5.2	0.86
Laterality	96 right 90 left	93 right 93 left	0.76

Numbers reported in mean ± standard deviation

Fig. 1. Measurement of acetabular cup abduction and anteversion.

Discussion

To date, no studies have been conducted comparing supine DA to supine DL approaches with regard to acetabular cup positioning. The purposes of this study were to evaluate the difference in acetabular cup anteversion and abduction and to compare complications between supine DA and DL THAs. We found that cup anteversion tended to be higher in DA approaches with more cups placed outside the "safe zone." Complication, however, was not increased in the DA approach.

Our study has several limitations. Firstly, this is a retrospective control cohort study. The bias in patient selection, lack of randomization, and difference in operative techniques between surgeons might exist in this study. However, our study was designed to eliminate patient selection bias by matching two groups of patients with BMI, age, and gender. We did not analyze the outcomes for the senior authors individually, as both senior authors are high-volume surgeons who are well-experienced in DA and DL approaches, which could eliminate possible surgical technique bias [2, 5]. Secondly, the use of plain radiographs rather than CT scans to measure cup positioning may have led to slight variations based on patient pelvic tilt and rotation. Retroverted cups, although theoretically rare in the DA approach in experienced surgeons' hands, are difficult to identify on pelvis AP plain films alone, and oblique or cross table lateral radiographs are required. We used Martell Hip Analysis Suite to measure cup abduction and version angles, and the reliability of this software has been previously demonstrated [5]. Thirdly, we did not measure the rotational position of the femoral stem in the femoral canal. Finally, short-term follow-up on these patients may not have captured all of the complications from these surgical approaches.

Dislocation, which is a multifactorial issue, is one of the most common complications after THA [27, 30]. Precise implant positioning is important for postoperative function and stability [1, 4, 6, 13, 15, 20]. The radiological safe zone of 40° ± 10° abduction and 15° ± 10° anteversion for acetabular component position was described by Lewinnek et al. [12], and cups placed outside this zone had been shown to have 4–6.9 higher dislocation rates than those within it [4, 9, 10, 12]. Although optimal cup position has been extensively described, there is limited literature on the factors influencing acetabular cup positioning. Some authors have demonstrated that surgical approach is a risk factor that influences cup malposition [5, 28], while others have failed to demonstrate it [2].

The average abduction angles for the DA (47.6°) and DL (46.2°) approaches in our study were comparable to those reported in literature, ranging from 39.3° to 47.1° for the DA approach and 42.7° to 45° for the DL approach [3, 14, 18, 19, 24, 28]. Our study showed that cup anteversion was higher in the DA approach (18.1° ± 5.2°) compared to the DL approach (15.0° ± 4.9°) and DA hips also had more cup anteversion outside of the safe zone than the DL approach (9.7% vs 3.2%). This finding supports a previous study by Takazawa et al. comparing the lateral decubitus DL approach to the supine DA approach [28]. They demonstrated that mean cup anteversion angles with the DL approach (17.3° ± 10.0°) were significantly lower than the early-stage DA approach (26.6° ± 8.1°) and the late-stage DA approach (21.0° ± 8.0°). However, in their study, the standard deviation of cup anteversion with the DL approach was significantly larger than the early and late DA approaches. In our study, the standard deviation of cup anteversion was similar between groups. For the study by Takazawa et al., the dislocation rate was 2.2% (5/224) in the DL approach, 4.2% (3/72) in the early DA approach, and 0.4% (1/270) in the late DA approach [28]. The dislocation rate was lower in our study, as there was only one dislocation (0.5%) in the DA group and no dislocations in the DL group.

Cup anteversion has also been studied using the DA approach or comparing the DA approach to the posterior approach with or without the use of intraoperative fluoroscopic guidance. In general, studies have reported mixed results with regard to cup anteversion using the DA approach. Matta et al. reported on 458 THAs performed through the DA approach with fluoroscopic guidance and found a mean cup anteversion of 19.4° ± 5.2° with 96% of the cups within the target anteversion range of 10°–25° [14]. With regard to comparative studies, Nakata et al. compared the DA approach to the posterior approach and found that cup anteversion angle in the DA approach (19.6° ± 0.5°) was significantly higher than the posterior approach (17.9° ± 0.6°) [18]. They found that 99% of the DA group was within the Lewinnek safe zone, but only 91% of cups in the posterior approach group were within the safe zone. Barrett et al. reported a significantly lower mean and standard deviation for cup anteversion (20.1° ± 5.9°) with fluoroscopically guided DA approach compared to the posterior approach (25.8° ± 8.1°) [3]. Rathod et al. demonstrated that mean cup anteversion angles with the DA approach (13.3° ± 4.0°) were significantly lower than THAs performed during the learning curve stage of the DA approach (20.2° ± 6.3°) and posterior approach (24.0 ± 8.7°) [24]. They also determined that the anteversion safe zone was achieved more often in the DA group (97%) than in the posterior approach group (77%). Our study was comparable to these studies with regard to mean cup anteversion angle in the DA approach. However, a lower rate of anteversion angles within the Lewinnek safe zone was achieved in our DA patients (90.3%) compared to those in the studies by Nakata et al. (99%) and Rathod et al (97%) [18, 24].

Despite the higher cup anteversion angles and more acetabular components outside of the safe zone in the DA approach, our study did not find any significant differences in complications between DA and DL approaches, including dislocation, PJI, and aseptic component loosening. As previously mentioned, dislocation after THA is a multifactorial issue involving patient and surgical factors [27, 30]. Acetabular component malposition is only one factor that contributes to increased dislocation rates, as other factors include limb-length discrepancy, component impingement, bearing surface wear, pelvic osteolysis, and revision surgery [11, 12, 23]. Components with high degrees of anteversion correlate with an increased prevalence of anterior dislocation [4, 13, 20], while those with retroversion correlate with an increased risk of posterior dislocation [4, 12]. Thus, care must be taken to place the acetabular component in the ideal location. For surgeons who perform the DA approach, understanding the tendency of anteverting the cup must be kept in mind so that implant position can be appropriately adjusted. Intraoperative fluoroscopic guidance can be used during the DA approach to improve acetabular component placement in both abduction and anteversion angles [14, 24].

In summary, there is a tendency to antevert the acetabular cup when performing THAs using the DA approach, and one must be mindful of this to adjust implant positioning. Whether cup positioning outside of the safe zone is associated with poor clinical outcomes remains to be determined. Further studies are needed to evaluate the incidence of dislocation and its association with anteversion in the DA approach, but our findings highlight the tendency to antevert the acetabular component when utilizing the DA approach for THA.

Compliance with Ethical Standards

Conflict of Interest: Chi-Lung Chen, MD; Sara Low, MD; Wei-Ming Lin, MD; and Karthikeyan Chinnakkannu, MBBS, MS, have declared that they have no conflict of interest. Zachary D. Post, MD, reports personal fees from Smith and Nephew, Stryker, DePuy, and OrthoDevelopment, outside the work. Alvin C. Ong, MD, reports personal fees from Stryker and Smith & Nephew, outside the work. Fabio R. Orozco, MD, reports personal fees from Stryker, outside the work. Antonia F. Chen, MD, MBA, reports other support from SLACK publishing, research support from 3M and Myoscience, non-financial support from Joint Purification Systems, and personal fees from ACI, outside the work.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Informed Consent: Informed consent was waived from all patients for being included in the study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

References

1. Barrack RL. Dislocation after total hip arthroplasty: implant design and orientation. *J Am Acad Orthop Surg*. 2003; 11: 89-99.
2. Barrack RL, Krempec JA, Clohisy JC, et al. Accuracy of acetabular component position in hip arthroplasty. *J Bone Joint Surg Am Vol*. 2013; 95: 1760-1768.
3. Barrett WP, Turner SE, Leopold JP. Prospective randomized study of direct anterior vs postero-lateral approach for total hip arthroplasty. *J Arthroplast*. 2013; 28: 1634-1638.
4. Biedermann R, Tonin A, Krismer M, et al. Reducing the risk of dislocation after total hip arthroplasty: the effect of orientation of the acetabular component. *J Bone Joint Surg Br Vol*. 2005; 87: 762-769.
5. Callanan MC, Jarrett B, Bragdon CR, et al. The John Charnley Award: risk factors for cup malpositioning: quality improvement through a joint registry at a tertiary hospital. *Clin Orthop Relat Res*. 2011; 469: 319-329.
6. Coventry MB, Beckenbaugh RD, Nolan DR, et al. 2,012 total hip arthroplasties. A study of postoperative course and early complications. *J Bone Joint Surg Am Vol*. 1974; 56: 273-284.
7. D'Lima DD, Urquhart AG, Buehler KO, et al. 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 Vol*. 2000; 82: 315-321.
8. Elson L, Dounchis J, Illgen R, et al. Precision of acetabular cup placement in robotic integrated total hip arthroplasty. *Hip Int: J Clin Exp Res Hip Pathol Ther*. 2015.
9. Jain S, Aderinto J, Bobak P. The role of the transverse acetabular ligament in total hip arthroplasty. *Acta Orthop Belg*. 2013; 79: 135-140.
10. Jolles BM, Zangger P, Leyvraz PF. Factors predisposing to dislocation after primary total hip arthroplasty: a multivariate analysis. *J Arthroplast*. 2002; 17: 282-288.
11. Kennedy JG, Rogers WB, Soffe KE, et al. Effect of acetabular component orientation on recurrent dislocation, pelvic osteolysis, polyethylene wear, and component migration. *J Arthroplast*. 1998; 13: 530-534.
12. Lewinnek GE, Lewis JL, Tarr R, et al. Dislocations after total hip-replacement arthroplasties. *J Bone Joint Surg Am Vol*. 1978; 60: 217-220.
13. Malviya A, Lingard EA, Malik A, et al. Hip flexion after Birmingham hip resurfacing: role of cup anteversion, anterior femoral head-neck offset, and head-neck ratio. *J Arthroplast*. 2010; 25: 387-391.
14. Matta JM, Shahrdar C, Ferguson T. Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. *Clin Orthop Relat Res*. 2005; 441: 115-124.
15. McCollum DE, Gray WJ. Dislocation after total hip arthroplasty. Causes and prevention. Clin Orthop Relat Res. 1990:159–170.
16. Moskal JT, Capps SG. Acetabular component positioning in total hip arthroplasty: an evidence-based analysis. *J Arthroplast*. 2011; 26: 1432-1437.
17. Mouilhade F, Matsoukis J, Oger P, et al. Component positioning in primary total hip replacement: a prospective comparative study of two anterolateral approaches, minimally invasive versus gluteus medius hemimyotomy. *Orthop Traumatol, Surg Res: OTSR*. 2011; 97: 14-21.
18. Nakata K, Nishikawa M, Yamamoto K, et al. A clinical comparative study of the direct anterior with mini-posterior approach: two consecutive series. *J Arthroplast*. 2009; 24: 698-704.
19. O'Brien DA, Rorabeck CH. The mini-incision direct lateral approach in primary total hip arthroplasty. *Clin Orthop Relat Res*. 2005; 441: 99-103.
20. Odri GA, Padiolleau GB, Gouin FT. Oversized cups as a major risk factor of postoperative pain after total hip arthroplasty. *J Arthroplast*. 2014; 29: 753-756.
21. Parratte S, Argenson JN, Flecher X, et al. Computer-assisted surgery for acetabular cup positioning in total hip arthroplasty: comparative prospective randomized study. *Rev Chir Orthop Reparatrice Appar Mot*. 2007; 93: 238-246.

22. Parvizi J, Gehrke T. International consensus group on periprosthetic joint I. Definition of periprosthetic joint infection. *J Arthroplast*. 2014; 29: 1331.
23. Parvizi J, Sharkey PF, Bissett GA, et al. Surgical treatment of limb-length discrepancy following total hip arthroplasty. *J Bone Joint Surg Am Vol*. 2003; 85-A: 2310-2317.
24. Rathod PA, Bhalla S, Deshmukh AJ, et al. Does fluoroscopy with anterior hip arthroplasty decrease acetabular cup variability compared with a nonguided posterior approach? *Clin Orthop Relat Res*. 2014; 472: 1877-1885.
25. Saxler G, Marx A, Vandevelde D, et al. The accuracy of free-hand cup positioning–a CT based measurement of cup placement in 105 total hip arthroplasties. *Int Orthop*. 2004; 28: 198-201.
26. Sendtner E, Schuster T, Worner M, et al. Accuracy of acetabular cup placement in computer-assisted, minimally-invasive THR in a lateral decubitus position. *Int Orthop*. 2011; 35: 809-815.
27. Soong M, Rubash HE, Macaulay W. Dislocation after total hip arthroplasty. *J Am Acad Orthop Surg*. 2004; 12: 314-321.
28. Takazawa M, Iida S, Suzuki C. Does surgical approach influence the position of acetabular and femoral component in total hip arthroplasty? Comparison between direct anterior and lateral approach. *J Bone Joint Surg Br Vol*. 2012; 94-B: 187.
29. Teet JS, Skinner HB, Khoury L. The effect of the "mini" incision in total hip arthroplasty on component position. *J Arthroplast*. 2006; 21: 503-507.
30. Widmer K-H. Is there really a "safe zone" for the placement of total hip components? *Bioceram Altern Bearings Joint Arthroplasty Ceram Orthop*. 2006; 249–252.
31. Williams S, Leslie I, Isaac G, et al. Tribology and wear of metal-on-metal hip prostheses: influence of cup angle and head position. *J Bone Joint Surg Am Vol*. 2008; 90(Suppl 3): 111-117.
32. Zhan C, Kaczmarek R, Loyo-Berrios N, et al. Incidence and short-term outcomes of primary and revision hip replacement in the United States. *J Bone Joint Surg Am Vol*. 2007; 89: 526-533.