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CLINICAL RESEARCH

Does Fluoroscopy Improve Acetabular Component Placement in Total Hip Arthroplasty?

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Abstract

Background The success of THA largely depends on correct placement of the individual components. Traditionally, these have been placed freehand using anatomic landmarks, but studies have shown poor accuracy with this method.

Questions/purposes Specifically, we asked (1) does using fluoroscopy lead to more accurate and greater likelihood of cup placement with the Lewinnek safe zone than does freehand cup placement; (2) is there a learning curve associated with the use of fluoroscopy for cup placement; (3) does the use of fluoroscopy increase operative time; and (4) is there a difference in leg length discrepancy between freehand and fluoroscopic techniques?

Methods This series consisted of 109 consecutive patients undergoing primary THA, conversion of a previous hip surgery to THA, and revision THA during a 24-month period. No patients were excluded from analysis during this time. The first 52 patients had cups placed freehand, and then the next 57 patients had acetabular components placed using fluoroscopy; the analysis began with the first patient treated using fluoroscopy, to include our initial experience with the technique. The abduction, version, and limb length discrepancy were measured on 6-week postoperative pelvic radiographs obtained with the patient in the supine position. Operative time, sex, age, BMI, diagnosis, operative side, and femoral head size were recorded as possible confounders.

Results Cups inserted freehand were placed in the ideal range of abduction (30°–45°) and anteversion (5°–25°) 44% of the time. With fluoroscopy, placement in the Lewinnek safe zone for both measures significantly increased to 65%. The odds of placing the cup in the Lewinnek safe zone for abduction and version were 2.3 times greater with the use of fluoroscopy (95% CI, 1.2–5.0; $p = 0.03$). Patients undergoing primary THAs (32 freehand, 35 C-arm) had cup placement in the safe zone for abduction and version 44% of the time freehand and 57% of the time with fluoroscopy, which failed to reach statistical significance. There was no difference in operative time, patient age, sex, operative side, diagnosis, limb length discrepancy, or femoral head size between the two groups.

Conclusions The use of fluoroscopy to directly observe pelvic position and acetabular component placement increased the success of placement in the Lewinnek safe zone in this cohort of patients having complex and primary THAs. This is a simple, low-cost, and quick method for increasing successful acetabular component alignment. The study population included a large proportion of patients

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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having complex THAs, and further validation of this technique in patients undergoing straightforward, primary THAs needs to be done to understand if similar gains in accuracy for component placement can be expected in that group.
Level of Evidence Level III, therapeutic study. See the Instructions for Authors for a complete description of levels of evidence.

Introduction

The clinical success of THA depends in large part on correct positioning of the individual components. One of the most common complications after THA is dislocation. The safe zone of 40° ± 10° abduction and 15° ± 10° anteversion for acetabular component position was described by Lewinnek et al. [11], and cups placed outside this zone have a higher dislocation rate [15]. Furthermore, cups placed outside this safe zone also experience higher biomechanical stresses leading to increased rates of polyethylene wear and osteolysis, thereby decreasing the longevity of the implant [9, 18]. We defined the ideal position of the acetabular component as 30° to 45° abduction and 5° to 25° anteversion, based on the principles of the Lewinnek safe zone.

Traditionally, cups have been inserted freehand using anatomic landmarks including the transverse and sagittal planes of the patient's body on the operating table. Using these landmarks the surgeon must assume the patient is in the perfect lateral position and that the coronal plane of the body is collinear with the anterior pelvic plane to place the acetabular component relative to the anatomic planes described by Murray [16]. Zhu et al. [22] reported that only 6.1% of patients placed in the lateral decubitus position had no pelvic tilt, whereas 55.5% of patients had some degree of posterior pelvic tilt and 38.4% had some degree of anterior pelvic tilt. Variations in anterior or posterior pelvic tilt tend to bias cup insertion into retroversion or excessive anteversion, respectively. A study using computer navigation showed that the position of the pelvis shifts during different stages of hip arthroplasty, moving to an average of 18° flexion during hip dislocation [4]. Uncertain pelvic position likely accounts for the low accuracy of cup placement by freehand methods reported by Callanan et al. [3]. In a large series with more than 1800 patients operated on by high-volume surgeons specializing in adult reconstruction at a tertiary-level referral hospital, only 48% of the cups inserted freehand were correctly placed in the Lewinnek safe zone for abduction and anteversion [3]. Given these factors and the importance of correct acetabular component placement, we speculated that reaming and cup insertion under fluoroscopic observation could offer advantages over the traditional freehand technique.

The purpose of this study was to compare the accuracy of acetabular components placed using freehand and fluoroscopic techniques. Specifically, we asked (1) if using fluoroscopy led to more accurate and greater likelihood of cup placement in the Lewinnek safe zone; (2) is there a learning curve associated with the use of fluoroscopy for cup placement; (3) does the use of fluoroscopy alter operative time; and (4) is there a difference in leg length discrepancy between freehand and fluoroscopic techniques? This study was approved by our institutional review board.

Patients and Methods

Patients

This was a retrospective analysis of radiographic outcomes of acetabular component placement in THA. Patients in the cohort were identified by a query of our institution's electronic orthopaedic trauma and billing database searching for Current Procedural Terminology codes 21730 (primary THA), 27132 (conversion of previous hip surgery to THA), 27134 (THA revision of both components) recorded by the senior authors (MSV, MJW). The diagnoses that led to THA included acetabular fracture, femoral neck fracture, osteoarthritis, avascular necrosis, and failed open reduction and internal fixation of a previous hip fracture. Variables collected included patient sex, age, BMI, operative side, diagnosis, femoral component head size, and operative time (Table 1). All patients initially identified in our query had acceptable imaging and documentation of the variables to be collected and therefore were included in the study. This series consisted of 109 consecutive patients undergoing THA, conversion of a previous hip surgery to THA, and revision THA during a 24-month period. No patients were excluded from analysis during this time. The first 52 patients had cups placed freehand, and the next 57 patients had acetabular components placed using fluoroscopy; the analysis began with the first patient treated using fluoroscopy, to include our initial experience with the technique. Of the patients, 67 (61%) had primary THAs and no prior hip surgery (32 in the freehand group and 35 in the fluoroscopic-assisted group). Patients with acetabular fractures who underwent THA were included with the revision or conversion group given the complexity of the case and frequent use of supplemental internal fixation. All C-arm cases, starting with the first one, were included to be able to evaluate the learning curve; none was excluded as a part of a break-in period.

Table 1. Characteristics of freehand and C-arm cup positioning groups

Variable	Freehand (n = 52)	C-arm (n = 57)	p value
Age of patient (years)	62.8 ± 15.6	59.2 ± 13.7	0.20
BMI (kg/m^2)	27.1 ± 5.4	29.6 ± 6.4	0.03*
BMI greater than 30	14 (27%)	28 (49%)	0.02*
Gender			0.70
Male	28 (54%)	28 (49%)	
Female	24 (46%)	29 (51%)	
Side			1.00
Left	23 (44%)	26 (46%)	
Right	29 (56%)	31 (54%)	
Site			0.25
Massachusetts General Hospital	35 (67%)	32 (56%)	
Brigham and Women's Hospital	17 (33%)	25 (44%)	
Injury type			0.22
Acetabular fracture	16 (31%)	11 (19%)	
Femoral head or neck fracture	13 (25%)	13 (23%)	
Other fracture	3 (6%)	7 (12%)	
Avascular necrosis	0 (0%)	4 (7%)	
Nontrauma	20 (39%)	22 (39%)	
Head size (cm)			0.10
32	14 (27%)	25 (44%)	
36	36 (69%)	28 (49%)	
40	2 (4%)	4 (7%)	
Operative time (minutes)	141 ± 56	142 ± 47	0.91

* Statistically significant.

Surgical Techniques: Freehand and C-arm (Fluoroscopy)

All patients in both groups were placed in the lateral decubitus position and held in place with a pegboard. The study population included patients with various diagnoses leading to the need for THA, as detailed above, therefore different approaches were used depending on the disorder to be addressed. A standard anterolateral approach was used most often, but for revision or acetabulum fracture cases, the posterior approach and the extended iliofemoral approach also were used. Internal landmarks referenced during freehand insertion include the ischium, ilium, pubis, and transverse acetabular ligament. In addition to referencing internal and external landmarks, an external aiming arm to estimate version and abduction was used during freehand insertion. No intraoperative plain films were obtained during freehand insertion. For the patients undergoing freehand surgery (freehand group), a partial capsulectomy was performed in every case to allow the use of internal landmarks to position the acetabular component. For the patients who had fluoroscopy (C-arm group), only a capsulotomy was necessary because the exposure of internal landmarks was of less importance given the ability to observe radiographic landmarks, reamer position, and cup insertion with fluoroscopy. The patients in the fluoroscopy group had the capsule preserved and repaired at the end of the procedure.

Patients having fluoroscopy were positioned in the lateral decubitus position on a peg board in the same fashion as patients having freehand surgery, and once the acetabulum was exposed the position of the C-arm was adjusted such that the fluoroscopic image obtained matched the patient's preoperative supine AP radiograph view of the pelvis. Specifically, the projection of the obturator foramen, appearance of the acetabulum, and position of the coccyx relative to the symphysis were evaluated subjectively by the surgeon as matching the preoperative supine AP radiograph view of the pelvis. Nishihara et al. [17] showed that the flexion angle of the pelvis when the patient is supine closely matches the functional pelvic position while standing in 90% of cases. True cup abduction can be affected by excessive pelvic flexion and extension; therefore, this was a critical step to ensure that we were placing the cup relative to the patient's functional pelvic position [19] (Fig. 1).

The acetabulum was reamed using occasional fluoroscopic spot images to confirm reamer position, size, and medialization. Reamer medialization and abduction angle were evaluated directly on the fluoroscopy image (Fig. 2A) and were estimated to be 40° from the midsagittal plane during cup insertion, as no radiographic measuring devices were used at the time of surgery. To determine the anteversion angle, the cup was first positioned so that the fluoroscopic image showed neutral version, meaning a perfect hemispheric view of the cup was obtained with no ellipse at the cup opening visible; then the cup positioning arm was moved in space relative to the starting position to an estimated 15° into anteversion (Fig. 2B). The acetabular component then was seated using fluoroscopic images to confirm that the opening ellipse of the cup matched the position of the reamer in 15° abduction and that it was seated against the medial wall of the acetabulum (Fig. 3). The femoral canal then was prepared. Once the surgeon was comfortable that the appropriate broach size had been achieved, a trial reduction was performed. Fluoroscopic images were used to check position of the femoral component and to ensure appropriate canal fill (Fig. 4). Leg length and offset were evaluated by comparing the fluoroscopic appearance of the lesser trochanter's relationship to the ischium of the surgically treated hip with fluoroscopic images of the contralateral hip.

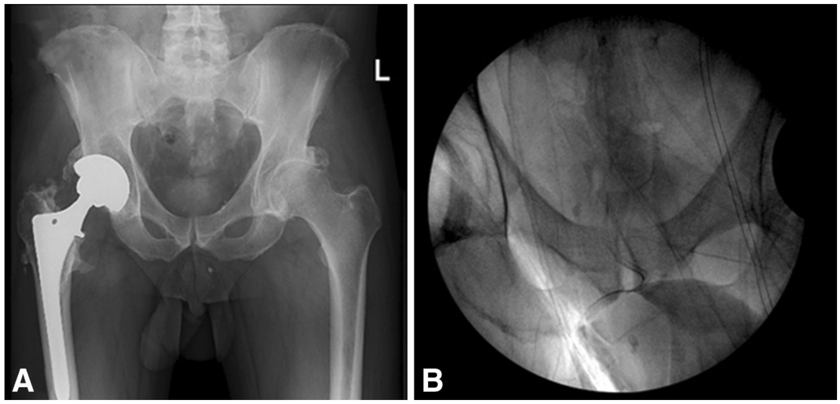

Fig. 1A–B (**A**) A preoperative AP radiograph of the pelvis was obtained with the patient supine and shows primary osteoarthritis of the left hip. (**B**) The fluoroscopic image was obtained with the patient in the lateral position on the operating room table with the C-arm beam positioned such that the intraoperative image matches the preoperative image. The shape of the obturator foramen and position of the coccyx relative to the pubic symphysis are noted by the surgeon.

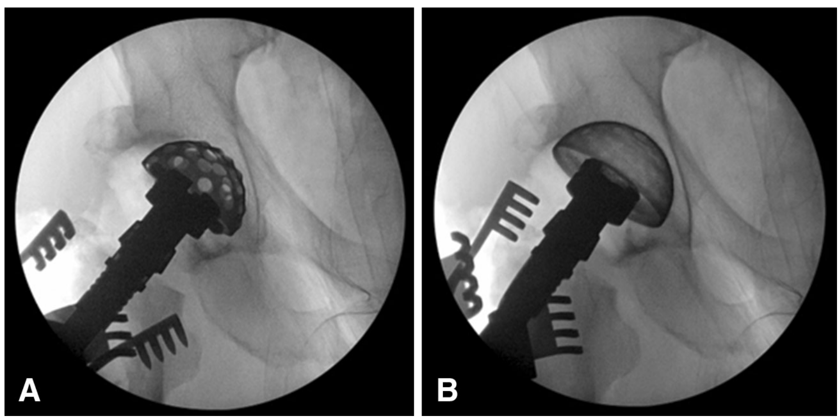

Fig. 2A–B (**A**) Reamer medialization and abduction are seen with spot fluoroscopic images during reaming. The surgeon estimates 40° abduction during reaming. The reamer is placed in neutral anteversion by obtaining a perfect hemispheric view of the reamer with no ellipse visible at the opening of the reamer cup. (**B**) The position of the insertion arm is noted in space and moved an estimated 15° in anteversion and the position checked with spot image on fluoroscopy.

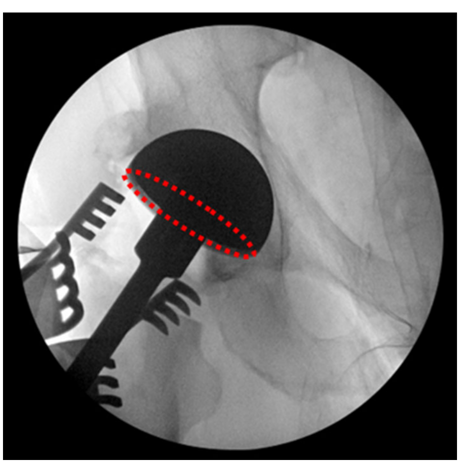

Fig. 3 The acetabular component is seated in 40° abduction and 15° anteversion, with the elliptical projection at the opening of the cup matching that of the insertion reamer in 15° abduction. Seating against the medial wall of the acetabulum is confirmed.

Radiographic Measurements

The position of the acetabular component was determined by measuring the 6-week postoperative AP radiographs of the pelvis obtained with the patient in the supine position, in the same fashion as preoperative imaging, using Martell Hip Analysis Suite™ (HAS) Version 8.0.4.3 (The University of Chicago, Chicago, IL, USA; http://ortho.biomed.imaging.home.comcast.net/). HAS uses an automated edge-detection capability and can be used to determine abduction and version angle of an acetabular component. In this study, an experienced operator (CB, JHM), blinded to the technique used for component insertion, obtained the measurements. The operator marked the ischial tuberosities to define the neutral transverse pelvic plane and then recorded three points around the femoral head and three points on the cup-opening ellipse to orient the software.

Fig. 4 A trial broach check assesses canal fill, offset, and limb length by comparing the position of the lesser trochanter with the ischial tuberosity and matched to the contralateral hip.

Accuracy and repeatability of HAS have been assessed and validated in several studies [2, 6, 12, 13].

Leg length measurements were similarly measured on 6-week postoperative AP radiographs of the pelvis, with the patient in the supine position and his or her feet together at the midline. Three patients in the freehand group and four in the C-arm group were excluded for having poor quality imaging that limited accuracy of limb length measurements. The measurements were obtained by drawing a line between the bottom of the teardrop bilaterally and measuring, perpendicularly, the distance between this line and the most prominent portion of the lesser tuberosity [10, 14]. The absolute difference was calculated and recorded.

Statistical Analysis

Continuous variables (age, BMI, and operative time) were compared between the freehand and C-arm groups using Student's t-test. Categorical and nominal data (sex, percentage obese [BMI > 30 kg/m^2], side, injury type, head size, and site [Massachusetts General and Brigham and Women's Hospitals]) were compared using Fisher's exact test or chi-square, as appropriate. Freehand and C-arm groups were compared with respect to the principles of the Lewinnek safe zone (abduction, 30°–45°; version, 5°–25°) [11] using the Z-test for two binary independent proportions. Levene's statistic was computed to assess homogeneity of variance with time in the C-arm group regarding radiographic measurements of abduction and version. Multivariable logistic regression was applied to control for confounding variables and to determine whether optimal positioning of abduction and version was more likely using the C-arm technique after adjustment for other covariates [8]. The adjusted odds ratio and 95% CI were calculated to estimate the odds of accurate cup positioning with respect to abduction and version between the two techniques, with significance assessed by the likelihood ratio test [5]. Subgroup analysis of the primary THAs was performed, evaluating radiographic outcome measures in the same fashion as described above. Statistical analysis was performed using SPSS Version 19.0 (SPSS Inc/IBM, Chicago, IL, USA). A two-tailed p less than 0.05 was considered statistically significant.

Results

The freehand and C-arm groups were comparable with respect to demographics, injury patterns, and operative time, except for higher BMI based on mean values ($p = 0.03$) and a higher proportion of obese patients (BMI > 30 kg/m^2) in the C-arm group ($p = 0.02$) (Table 1).

When considering all THAs in the cohort, the percentage of cases in which abduction and version in the Lewinnek safe zone were attained was greater using the C-arm technique (65% versus 44%; $p = 0.03$) (Fig. 5). Regarding placement of the cup, surgeons were able to achieve a greater percentage of cups placed from 30° to 45° abduction using the C-arm compared with the freehand technique (74% versus 58%), and a percentage of cups placed in 5° to 25° version (86% versus 74%) (Fig. 6). The odds of achieving accurate cup positioning for abduction and version were 2.3 times greater using the C-arm technique (95% CI, 1.2–5.0; $p = 0.03$). This finding was independent of age, BMI, and diagnosis and all other factors analyzed (Table 2). When considering only primary THAs in the cohort (32 freehand, 35 C-arm), acetabular components were placed with ideal abduction and version 44% of the time for freehand and 57% of the time when using fluoroscopy ($p = 0.33$). Cups were placed with ideal abduction by freehand technique in 56% of cases, and with fluoroscopy this increased to 63% ($p = 0.63$). Optimal version was obtained in 72% of freehand cases, and increased to 89% with fluoroscopy ($p = 0.12$) (Table 3).

With the numbers available, there was no discernible learning curve for using this technique. Cup positioning in the Lewinnek safe zone for abduction and version was achieved in 55% of the first 20 C-arm cases, 70% of the second 20 C-arm cases, and 71% of the last 17 C-arm cases ($p = 0.51$, chi-square test of trend). Variability in cup positioning did not change during the 57 consecutive C-arm cases (Levene's test of homogeneity of variance, $p = 0.26$ and 0.21 for abduction and version, respectively).

There was no difference in operative times between the two groups. The mean operative time from incision to end of surgery for the C-arm group was 142 ± 47 minutes versus 141 ± 56 minutes for the freehand group ($p = 0.91$).

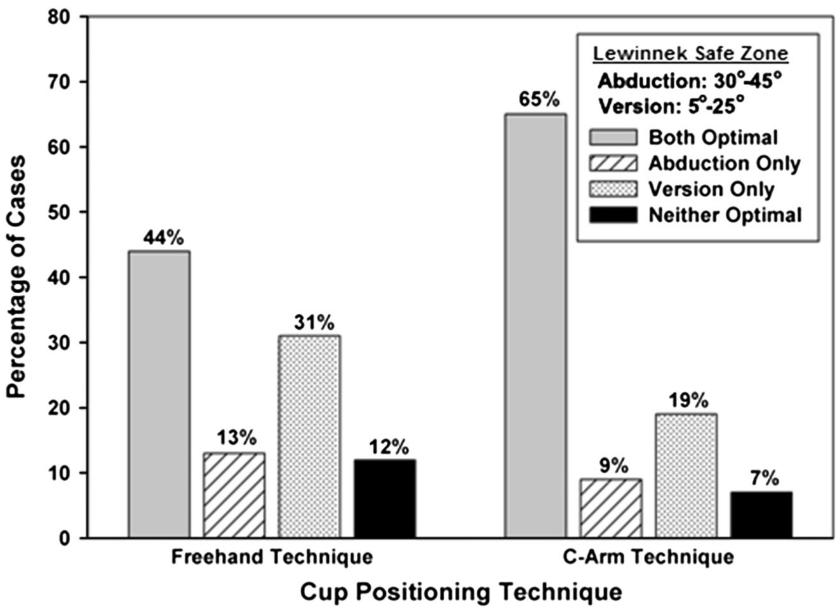

Fig. 5 The bar graph shows the percentage of cases with acetabular components placed in the Lewinnek safe zone range for abduction (30°–45°), version (5°–25°), both measures, or neither, for the freehand and C-arm techniques.

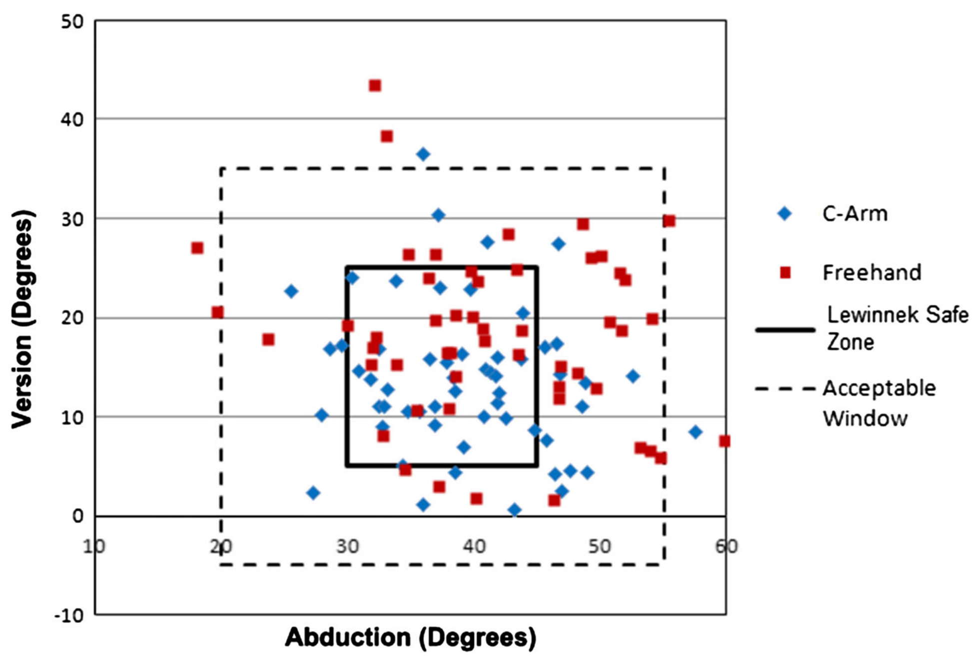

Fig. 6 The scatterplot shows the distribution of acetabular component placement with version on the Y-axis and abduction on the X-axis. The dashed line represents the limits of acceptable cup placement (−5° to 35° version; 20°–55° abduction). The solid line represents limits of the Lewinnek safe zone for cup placement (5°–25° version; 30°–45° abduction).

Operative time in the C-arm group remained comparable with time, with ANOVA indicating no significant change ($p = 0.41$).

Postoperative limb length discrepancy for all patients having THAs, measured radiographically, was not different between the two groups. The measured absolute mean limb length discrepancy was 6.1 mm in the C-arm group (SD, 4.4) and 6.9 mm in the freehand group (SD, 4.9) ($p = 0.35$). When the cohort was divided into THAs done in patients with traumatic or nontraumatic conditions, the measured

Table 2. Cup positioning results for freehand and C-arm techniques (all cases)

Criteria	Freehand (n = 52)	C-arm (n = 57)	p value
Abduction, degrees			
< 30	3 (6%)	4 (7%)	
30–45 (optimal)	30 (58%)	42 (74%)	
> 45	19 (36%)	11 (19%)	
Version, degrees			
< 5	3 (6%)	4 (7%)	
5–25 (optimal)	39 (75%)	49 (86%)	
> 25	10 (19%)	4 (7%)	
Both optimal	23 (44%)	37 (65%)	0.03*

* Statistically significant, Z-test for comparing two independent binary proportions.

Table 3. Cup positioning results for freehand and C-arm techniques (primary cases)

Criteria	Freehand (n = 32)	C-arm (n = 35)	p value*
Abduction, degrees			
< 30	2 (6%)	4 (11%)	0.62
30–45 (optimal)	18 (56%)	22 (63%)	
> 45	12 (38%)	9 (26%)	
Version, degrees			
< 5	2 (6%)	3 (8%)	0.12
5–25 (optimal)	23 (72%)	31 (89%)	
> 25	7 (22%)	1 (3%)	
Both optimal	14 (44%)	20 (57%)	0.33

* No significant group differences.

absolute limb length discrepancies again were not different (Fig. 7). Limb length discrepancy then was categorized in 5-mm increments (< 5 mm, 5–10 mm, 10–15 mm, and > 15 mm) and Pearson chi-square test indicated no difference between the two methods in the distribution of patients in the four categories for all cases (p = 0.64), THAs in patients with trauma (p = 0.53), and those done for patients with nontraumatic conditions (p = 0.44). Absolute limb length discrepancy of 15 mm or more was observed in 8% of patients for each method (Table 4). When evaluating primary THAs as a distinct subgroup, there were no differences in absolute limb length discrepancy distribution across the 5-mm increment groups for the two techniques when considering all cases (p = 0.23), those done for trauma (p = 0.99), and those done for nontraumatic causes (p = 0.06) (Table 5).

Discussion

The longevity and clinical success of a THA relies on femoral and acetabular components being placed in the proper position. Malposition of the acetabular component leads to higher rates of dislocation, increased bearing wear, and liner fracture [9, 11]. Component malposition may be the result of the surgeon's misinterpretation of the position of the patient's pelvis on the operating table or obscured internal and external landmarks by body habitus and the general trend toward the use of smaller incisions or minimally invasive techniques [22]. Furthermore, the majority of primary THAs in the United States are performed by surgeons who do 10 or fewer per year, and low surgical

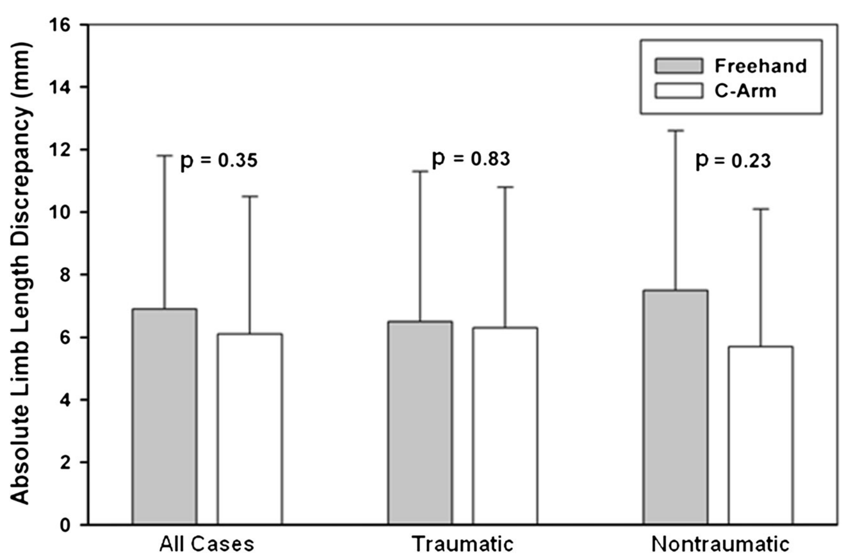

Fig. 7 The bar graph shows the average absolute limb length discrepancy for the freehand and C-arm groups for all cases.

Table 4. Limb length discrepancy (all cases), absolute value categories stratified by method

Category	Freehand	C-arm	p value (chi-square test)
All THAs	n = 49	n = 53	0.64
< 5 mm	19 (39%)	24 (45%)	
5–9.9 mm	16 (33%)	19 (36%)	
10–14.9 mm	10 (20%)	6 (11%)	
≥ 15 mm	4 (8%)	4 (8%)	
Traumatic	n = 30	n = 33	0.53
< 5 mm	11 (37%)	14 (42%)	
5–9.9 mm	12 (40%)	13 (39%)	
10–14.9 mm	5 (17%)	2 (6%)	
≥ 15 mm	2 (7%)	4 (12%)	
Nontraumatic	n = 19	n = 20	0.44
< 5 mm	8 (42%)	10 (50%)	
5–9.9 mm	4 (21%)	6 (30%)	
10–14.9 mm	5 (26%)	4 (20%)	
≥ 15 mm	2 (11%)	0 (0%)	

No significant differences between methods in the ordinal categories of absolute limb length discrepancy.

Table 5. Limb length discrepancy (primary cases), absolute value categories stratified by method

Category	Freehand	C-arm	p value (chi-square test)
All THAs	n = 31	n = 35	0.23
< 5 mm	13 (42%)	14 (40%)	
5–9.9 mm	6 (19%)	14 (40%)	
10–14.9 mm	9 (29%)	5 (14%)	
≥ 15 mm	3 (10%)	2 (6%)	
Traumatic	n = 16	n = 18	0.99
< 5 mm	7 (44%)	8 (44%)	
5–9.9 mm	4 (25%)	5 (28%)	
10–14.9 mm	4 (25%)	4 (22%)	
≥ 15 mm	1 (6%)	1 (6%)	
Nontraumatic	n = 15	n = 17	0.06
< 5 mm	6 (40%)	6 (35%)	
5–9.9 mm	2 (13%)	9 (53%)	
10–14.9 mm	5 (33%)	1 (6%)	
≥ 15 mm	2 (13%)	1 (6%)	

No significant differences between methods in the ordinal categories of absolute limb length discrepancy.

volume has been correlated with higher rates of component malposition, dislocation, and complication after surgery [7]. Callanan et al. reported that even high-volume, experienced hip surgeons have great difficulty properly positioning the acetabular component using freehand techniques [3]. The purpose of our study was to determine if the use of fluoroscopy could improve acetabular component positioning.

Our study is limited because the series of patients have not been followed long term to observe whether radiographic outcomes correlate with clinical outcomes. Historic data suggest that they do [1]. Furthermore, the senior authors (MSV, MJW) are primarily traumatologists who perform elective and posttraumatic THAs but may be more facile with fluoroscopy than a general or arthroplasty-trained orthopaedist. Total time in the operating room was not recorded for this study. While the use of fluoroscopy during the surgery did not prolong the case, setup and take down of the C-arm, and how that figures into total time in the operating room and potential costs associated with its use were not analyzed. The radiation exposure to the patient and surgeon was not recorded during this study, but these data were reported for numerous orthopaedic procedures that use fluoroscopy [20]. We did not analyze the outcomes for the senior authors individually. Furthermore, although the anterolateral approach was used most often, and posterior and iliofemoral approaches were used in some revision and acetabular fracture cases, the results of the individual approaches were not analyzed separately. Limb length discrepancy was measured on postoperative plain films of the pelvis taken with the patient in the supine position, which were obtained 6 weeks after surgery. Three-foot films with the patient standing or CT scanograms typically are preferred for the most accurate limb length measurements. Furthermore, clinical measures of limb length and patient-reported limb length discrepancy were not recorded. Finally, cup version was measured on postoperative AP radiographs of the pelvis with the patient in the supine position. While this reveals the cup's version, without an orthogonal view or CT scan, one cannot know if the cup is in anteversion or retroversion. The surgical technique of placing the cup in neutral version and getting a perfect hemispheric fluoroscopic image of the cup, then moving the aiming arm 15° into anteversion would decrease the risk for retroversion owing to unclear pelvic positioning, but theoretically surgeon error still could allow for retroverted cup placement.

The surgeons evaluated in this study were 2.3 times more likely to place the cup in the Lewinnek safe zone using fluoroscopy than standard acetabular position techniques for our cohort having primary and complex revision THAs. In the 52 cases done using standard component positioning techniques, before the introduction of fluoroscopy, the surgeons placed the cup in the Lewinnek safe zone for abduction and version in 58% and 75% of the cases, respectively, yet only placing the cup in the safe zone for both parameters 44% of the time. This compares with reported rates of proper cup positioning. Callanan

Fig. 8 A postoperative radiograph shows bilateral THAs. The left hip was placed by the same surgeon using fluoroscopy assistance, whereas the right was placed freehand.

et al. [3] reported experienced arthroplasty surgeons placed the cup in the safe zone for abduction and version in 62% and 79% of cases, respectively, and in the safe zone for both parameters in only 48% of cases. By introducing fluoroscopy, the surgeons in our study were able to improve their ability to position the acetabular component in the safe zone for abduction and version in 74% and 86% of cases, respectively, while meeting safe zone parameters in 65% of cases, which was an improvement over freehand insertion (Fig. 8). These results were achieved despite including complex reconstructions and revisions. In addition, ½ of the patients in the C-arm group were obese, which is a known risk factor for cup malposition [3]. Known risk factors for cup malpositioning include obesity, low-volume surgeon, and a minimally invasive approach [3]. Furthermore, component malposition has been found to be the primary cause of unstable THAs [21]. Freehand insertion of the acetabular component requires adequate exposure to observe the acetabulum and surrounding anatomic landmarks while understanding the precise position of the pelvis in space and the changes in position that occur during the case. Factors such as obesity and smaller incisions during minimally invasive approaches can limit observation and appreciation of pelvic position by obscuring palpable internal and external landmarks. Furthermore, obesity likely leads to decreased ability of patient positioning devices to hold the pelvis static during the entirety of the procedure, therefore the propensity to position cups poorly in these cases. Our study suggests that the use of fluoroscopy in patients undergoing complex THA reduces the reliance on palpable internal and observable external landmarks by giving the surgeon a direct view of the patient's pelvis on the table regardless of the patient's body habitus or the adequacy of surgical exposure. Fluoroscopy offers the surgeon another tool during the decision-making process when placing the acetabular component by making radiographic landmarks available during the procedure.

When primary THAs were evaluated as a distinct subgroup, gains in accuracy for cup placement in the Lewinnek safe zone for abduction, version, and both measures combined were seen, but failed to reach statistical significance. The subset of primary THAs was considerably smaller than the entire cohort (66 cases of 109 total) leading to decreased statistical power to detect significant change.

The accuracy of cup placement did not increase with time after introducing fluoroscopy to the procedure, therefore there was no measurable learning curve with this alteration to the procedure.

The use of fluoroscopy did not prolong the duration of the case. Although our study shows no prolongation in duration or significant learning curve with the use of fluoroscopy-guided component placement, this may not be the case for the orthopaedist who does not routinely use fluoroscopy. Nevertheless, the fluoroscopic techniques necessary are not more rigorous than those used for treatment of a hip fracture and should be familiar to most orthopaedic surgeons.

The use of fluoroscopy did not result in a smaller absolute limb length discrepancy. With fluoroscopic assistance, the position of the lesser trochanter relative to the ischial tuberosity was compared with the nonoperative side to judge limb length, and this failed to produce a lower incidence of limb length discrepancy between the two groups. Interestingly, there were similar numbers of patients with a limb length discrepancy greater than 15 mm in the freehand and fluoroscopy groups, suggesting that fluoroscopy may not be useful in judging the degree of limb length discrepancy intraoperatively.

The current study is composed of a complex patient population, many of whom have had multiple hip surgeries, and had THAs for numerous diagnoses, including fractures of the proximal femur and acetabulum, and revision THAs. This is illustrated by the fact that only 61% of the patients included in the study underwent primary THAs. Furthermore, the operative times for each group averaged approximately 2.5 hours, illustrating the complexity of this cohort. The subgroup analysis of the primary THAs revealed a greater percentage of cups placed in the Lewinnek safe zone for abduction, version, and both measures combined, yet this failed to reach statistical significance. The size of the subset of primary THAs was underpowered for this analysis. Our cohort represents a large proportion of what would be considered complex THAs and the results in our study may not generalize to a cohort of simple, elective THAs. Readers should use caution when extrapolating our results to those of an elective arthroplasty practice comprised or mostly primary total joint arthroplasties. Future studies should seek to confirm that using fluoroscopy for acetabular component placement increases the accuracy of placement even in elective primary THAs. Furthermore, correlation between our observed radiographic endpoints with clinical endpoints, including patient-reported outcomes, dislocation rates, and rates of polyethylene wear, should be performed. The results of our study suggest that the use of fluoroscopy may increase accurate placement of acetabular components in the Lewinnek safe zone for surgeons performing a mix of primary and revision or complicated total joint arthroplasties.

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