Original Research

Does Structured Postgraduate Training Affect the Learning Curve in Direct Anterior Total Hip Arthroplasty? A Single Surgeon's First 200 Cases

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ABSTRACT

Background: The direct anterior approach (DAA) used for primary total hip arthroplasty has been shown to improve early postoperative outcomes, but prior studies have identified a marked learning curve for surgeons transitioning to this approach. However, these studies do not capture surgeons with postgraduate fellowship training in DAA. Therefore, the purpose of this study was to evaluate the learning curve by comparing perioperative outcomes for the first 100 to latter 100 cases and first 50 to final 50 cases.
Methods: The first 200 consecutive primary total hip arthroplasties performed by a single surgeon were prospectively followed up for up to 2 years postoperatively. Data on demographic and perioperative factors, 90-day readmissions, and short- and long-term complications were collected. Radiographic outcomes included acetabular cup anteversion and abduction measurements. Logistic regressions were used to calculate odds ratios and confidence intervals for surgical time greater than 2 hours.
Results: The first 100 and second 100 cases had significant differences in operative times (118.1 vs 110.4 minutes, $P = .009$), acetabular abduction (38.3 vs 35.5 degrees, $P = .001$) and anteversion (13.5 vs 15.1 degrees, $P = .009$), and incidence of neuropraxia (41 vs 9%, $P < .001$). Estimated blood loss, transfusions, discharge disposition, length of stay, readmission, and other complications had no statistical significance between the first and second 100 cases. The first 50 cases had higher odds of surgical time greater than 2 hours (odds ratio = 5.2, 95% confidence interval = 1.84-14.75, $P = .002$) than the final 50 cases.
Conclusions: When compared with the existing literature, incorporation of DAA into fellowship training can lead to reduction in fractures and reoperation rates.
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Introduction

The direct anterior approach (DAA) has a long history of use in orthopedics: descriptions by Heuter then Smith-Peterson, use in hip arthroplasty by Judet, and recent modifications by Matta [1,2]. The approach for total hip arthroplasty (THA) has gained popularity in recent years because of its reported benefits in recovery time, pain, functional outcomes, and decreased length of stay (LOS) [2-13]. Zhao et al. performed a randomized-controlled trial on 120 patients divided into DAA and posterolateral approaches for THA to determine differences in early postoperative outcomes. The study found that the DAA showed shorter LOS, lower serum markers of muscle damage, lower pain, and improved function at 3 months. In addition, lower variance in the cup inclination and anteversion angles have been reported using the DAA [9]. Taunton et al. randomized 116 primary THA patients into either DAA or mini-posterior approach and demonstrated improved early postoperative recovery for the DAA group but minimal difference past 2 months [14]. Similarly, Barrett et al. analyzed 87 patients randomized to direct anterior or posterolateral approaches and found improved functional outcomes in the early postoperative

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period for DAA patients, lower pain scores, and improvements in both stair climbing and walking at 6 weeks [10].

Despite these potential benefits, the DAA can be technically demanding, leading to a potential risk of increased complications and a significant learning curve [15,16]. Eto et al. found that in patients undergoing revision THA, the DAA was associated with earlier time to revision surgery compared with other approaches (3.0 ± 2.7 vs 12.0 ± 8.8 years, $P < .001$) [15]. The learning curve for the DAA has been well documented [2,6,17-21]. In addition, surgeons have often learned the approach through courses and observations of other surgeons, as opposed to fellowship training [2]. De Steiger et al. [17] performed an analysis of 5499 THAs in the Australian Joint Registry database, showing a significant learning curve in the DAA. For surgeons performing more than 100 cases, the revision rate decreased from 6% during the first 15 cases to 2% after 100 cases. The study found that a learning curve exists up to the first 50 cases, at which point the revision rate begins to reflect surgeons with more than 100 cases [17]. In a systematic review, Den Hartog analyzed 21 studies evaluating the learning curve of the DAA [18]. This review found improvements in operative time, blood loss, and complication rates as the learning curve progresses. However, there was a large variance in the number of cases required for the learning curve to complete, between 10 and 200 cases [18]. The occurrence of a learning curve is not unique to the DAA, they have also been found in other orthopedic procedures and different surgical specialties [22-24]. Usuelli et al. found that in total ankle arthroplasty, operative times, fractures, and radiographic outcomes improved over time until 28 cases were performed, demonstrating stabilization of the learning curve [24].

While a learning curve has been appreciated in the DAA, no studies have evaluated the learning curve in surgeons with postgraduate fellowship training in DAA. We hypothesize that formal training in the DAA allows for the learning curve to occur during training, thus reducing complications seen in the initial DAA cases when a surgeon is in practice. Therefore, this study was designed to evaluate the clinical and radiographic outcomes of a single, fellowship-trained arthroplasty surgeon's first 200 cases to assess the learning curve of the DAA in THA.

Material and methods

Institutional review board approval was obtained before investigation and data collection. This study is a prospectively collected case series of the first 200 consecutive, primary direct anterior THAs performed by a single arthroplasty fellowship-trained orthopedic surgeon. The surgeon was trained in the DAA during fellowship, as well as an additional post-fellowship hip surgery training for 3 months. No independent cases were performed during the post-fellowship training, which was completed in Switzerland at a hip clinic. Overall, the surgeon performed or was first assist on approximately 100 cases and observed 50 additional cases. After starting practice, the first 200 consecutive cases of primary THA undergoing DAA at a high-volume institution by the single surgeon were collected. Any revisions, conversion of previous hip surgery to THAs, or THAs performed via other approaches during this time were excluded. Exclusion for other approaches included 2 patients with developmental dysplasia of the hip who underwent THAs via posterior approach.

All DAAs were performed in a similar fashion. A Hana table (Mizuho OSI, Union City, CA) was used for patient positioning and manipulation of the operative leg. A standard DAA with a second-generation, wedge-tapered cementless femoral stem (Accolade II; Stryker, Mahwah, NJ) and press-fit acetabular cup (Trident; Stryker, Mahwah, NJ) was used in each case. Intraoperative fluoroscopy ensured appropriate acetabular and femoral component positioning.

Data were prospectively collected for the surgeon's first 200 DAA THA cases, occurring between April 2015 and May 2017. Patient demographics collected included age, body mass index, gender, and laterality of surgery. The primary outcomes were operative time, LOS, estimate blood loss, intraoperative fracture, and postoperative complications. Postoperative complications were defined as dislocation, fracture, and superficial or deep infection. Infections were defined as superficial surgical site infections, involving skin dehiscence and subcutaneous infection treated with local wound care only, and deep surgical site infections, involving the fascial layer and requiring surgical intervention. Secondary outcomes collected included acetabular cup anteversion, abduction, blood transfusion, postoperative pain, lateral femoral cutaneous nerve (LFCN) neuropraxia, discharge disposition, and 30- or 90-day readmission. Prolonged LOS was deemed to be 5 days and longer.

Data were collected for follow-up appointments at 2 weeks, 4 weeks, 3 months, 6 months, 1 year, and 2 years when possible. At postoperative visits, patients were assessed for pain, LFCN neuropraxia, component positioning, postoperative complications, and all-cause readmissions. In addition, the health system's electronic medical record was reviewed to assess for any readmissions.

Acetabular abduction and anteversion angles were measured using the method described by Widmer [25]. Using a plain anteroposterior pelvis radiograph, acetabular abduction was determined as the angle between the long axis of the acetabular component ellipse and a line perpendicular to the acetabular teardrop. The acetabular anteversion was determined by measuring the short axis of the ellipse (S) and total length (TL) of the acetabular cup. Then S/TL was used to calculated the anteversion [25]. Acetabular angles were compared to the ranges proposed by Lewinnek, anteversion 15 ± 10 degrees and abduction 40 ± 10 degrees, to ensure appropriate component placement [26]. The desired acetabular abduction angle of the operating surgeon was 38 ± 10 degrees while the previously described center-center technique was used for femoral stem placement [27]. Evaluation of acetabular component positioning was performed by 2 of the authors, and any discrepancies greater than 2 degrees were reevaluated by an independent secondary fellowship-trained arthroplasty surgeon.

All statistical analyses were performed with SPSS version 26 (IBM Corporation, Armonk, NY). Patient demographic and perioperative factors were compared using Fisher's exact test and chi-square test for categorical variables and independent samples t-test and Welch's t-test for continuous variables. Logistic regressions were used to calculate odds ratios (OR) and confidence intervals (CI) for surgical time greater than 2 hours. Tests were deemed significant with a P value less than 0.05, or, when applicable, a Holm-Bonferroni correction was performed to determine adjusted value.

The average age of the first 200 patients was 64.5 years (range: 25 to 94) with 129 females and 71 males. There were no differences between the first 100 and second 100 cases in age, body mass index, gender, or laterality of surgery (Table 1). Additional analyses were performed comparing the first 50 to the last 50 cases performed (cases 151 to 200). There were no differences in age, body mass index, gender, or laterality of surgery between the first 50 and last 50 cases (Table 2).

Results

Perioperative factors and radiographic parameters

The mean surgical time for the case series was 114.2 minutes (range: 61.2 to 187.8). There were differences between the first and second 100 cases compared among surgical time (118.1 ± 22.7 vs 110.4 ± 18.4 minutes, $P = .009$) (Fig. 1), but not in estimated blood loss (293.5 vs 249.5 milliliters, $P = .054$) (Fig. 2). The hospital LOS

Table 1
Factor and outcome comparison of first 100 to second 100 cases of anterior total hip arthroplasty.

Factors and outcomes	First 100 cases	Second 100 cases	P value
Demographics			
Age, years, mean ± SD	65.2 ± 14.4	63.8 ± 10.3	.440
Body mass index, kg/m^2	29.89 ± 5.38	30.15 ± 6.82	.201
Gender, percent female	62	67	.555
Laterality, percent right	60	51	.255
Perioperative factors			
Blood loss, milliliters, mean ± SD	293.5 ± 190.5	249.5 ± 122.2	.054
Surgical time, minutes, mean ± SD	118.1 ± 22.7	110.4 ± 18.4	**.009**
Surgical time >2 hours, percent	37	25	.092
Length of stay, days, mean ± SD	2.7 ± 1.7	2.3 ± 1.4	.062
Prolonged length of stay, percent	17	7	**.048**
Discharged to home, percent	74	81	.310
Radiographic parameters			
Cup abduction, degrees, mean ± SD	38.3 ± 5.6	35.5 ± 6.0	**.001**
Cup anteversion, degrees, mean ± SD	13.5 ± 4.4	15.1 ± 4.1	**.009**
Postoperative outcomes			
Transfusion, percent	5	7	.767
Hospital complication, percent	13	7	.238
Infection	5	6	1.000
Readmission, percent	3	3	1.000
Residual pain, percent	5	3	.721
LFCN neuropraxia, percent	41	9	**<.001**

Risk of adverse outcome in first group[a]	OR (95% CI)		P-value
Surgical time >2 hours	1.82 (0.98-3.41)		.060

CI, confidence interval; LFCN, lateral femoral cutaneous nerve; OR, odds ratio; SD, standard deviation.
Significant P values are bolded.
[a] When compared to second group, while controlling for age, gender, and laterality; goodness-of-fit appropriate multivariate regression models, P < .05. Adjusted significant P value set at 0.025 for regression analyses.

was longer in the first group (2.7 vs 2.3 days, $P = .062$) and had more patients with prolonged LOS (17 vs 7%, $P = .048$). Finally, acetabular abduction (38.3 vs 35.5 degrees, $P = .001$) and anteversion (13.5 vs 15.1 degrees, $P = .009$) (Fig. 3) were significantly different among the first and second 100 cases (Table 1).

Further comparison of the first and final 50 cases demonstrated differences in surgical times (121.0 ± 22.6 vs 107.4 ± 18.7 minutes,

$P = .001$), surgical times longer than 2 hours (44 vs 16%, $P = .004$), and LOS (3.0 vs 2.3 days, $P = .036$). Patients in the last 50 cases had less estimated blood loss and lower incidence of prolonged LOS, but this did not reach statistical significance. Acetabular abduction (40.2 vs 34.4 degrees, $P < .001$) was significantly different among the subgroups, but component anteversion was not (14.2 vs 15.2 degrees, $P = .240$) (Table 2).

Table 2
Factor and outcome comparison of first 50 cases to cases 151 to 200 (last 50 of 200 cases) of anterior total hip arthroplasty.

Factors and outcomes	First 50 cases	Last 50 cases	P value
Demographics			
Age, years, mean ± SD	65.7 ± 13.6	64.8 ± 10.5	.711
Body mass index, kg/m^2	29.78 ± 5.37	30.29 ± 6.64	.337
Gender, percent female	66	64	1.000
Laterality, percent right	66	46	.069
Perioperative factors			
Blood loss, milliliters, mean ± SD	322.0 ± 230.6	266.0 ± 140.5	.161
Surgical time, minutes, mean ± SD	121.0 ± 22.6	107.4 ± 18.7	**.001**
Surgical time >2 hours, percent	44	16	**.004**
Length of stay, days, mean ± SD	3.0 ± 1.6	2.3 ± 1.5	**.036**
Prolonged length of stay, percent	22	8	.091
Discharged to home, percent	76	80	.810
Radiographic parameters			
Cup abduction, degrees, mean ± SD	40.2 ± 5.3	34.4 ± 5.0	**<.001**
Cup anteversion, degrees, mean ± SD	14.2 ± 4.7	15.2 ± 3.8	.240
Postoperative outcomes			
Transfusion, percent	4	6	1.000
Hospital complication, percent	10	6	.715
Readmission, percent	2	6	.671
Residual pain, percent	4	2	.678
LFCN neuropraxia, percent	54	10	**<.001**

Risk of adverse outcome in first group[a]	OR (95% CI)		P value
Surgical time >2 hours	5.20 (1.84-14.75)		**.002**

CI, confidence interval; LFCN, lateral femoral cutaneous nerve; OR, odds ratio; SD, standard deviation.
Significant P values are bolded.
[a] When compared to second group, while controlling for age, gender, and laterality; goodness-of-fit appropriate multivariate regression models, P < .05. Adjusted significant P value set at 0.017 for regression analyses.
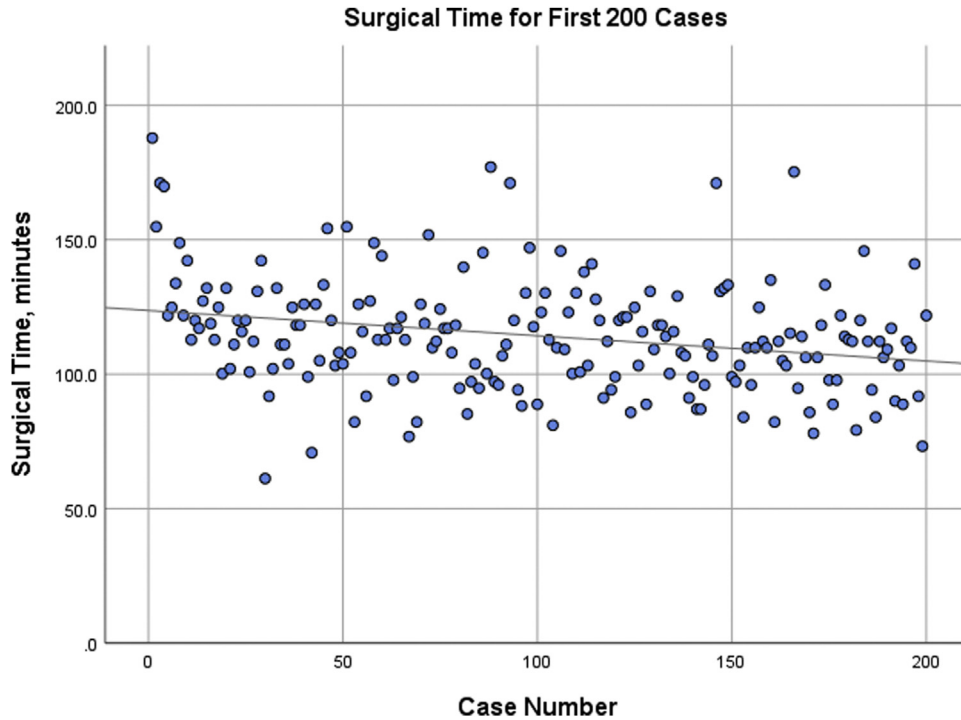
Surgical Time for First 200 Cases

Figure 1. Surgical time in consecutive primary total hip arthroplasty using anterior approach.

While controlling for age, gender, and laterality of surgery, the first 100 cases had higher odds of lasting greater than 2 hours (OR = 1.82, 95% CI = 0.98-3.41, P = .060; Table 1) than the second 100 cases. Furthermore, the first 50 cases had significantly higher odds of lasting longer than 2 hours than the last 50 cases (OR = 5.2, 95% CI = 1.84-14.75, P = .002; Table 2).

Postoperative outcomes

In the first 100 cases, there was one intraoperative fracture involving the tip of the greater trochanter. The patient had no postoperative weight-bearing precautions and was treated with weight-bearing as tolerated. The patient reported slight residual
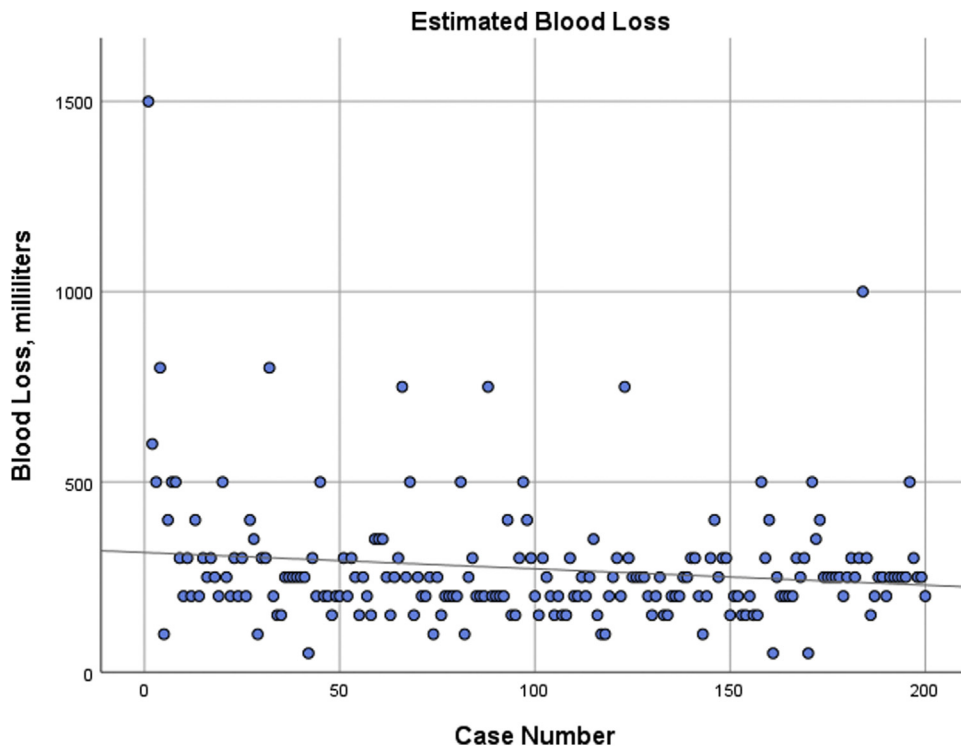
Estimated Blood Loss

Figure 2. Operative blood loss time in consecutive primary total hip arthroplasty using anterior approach.
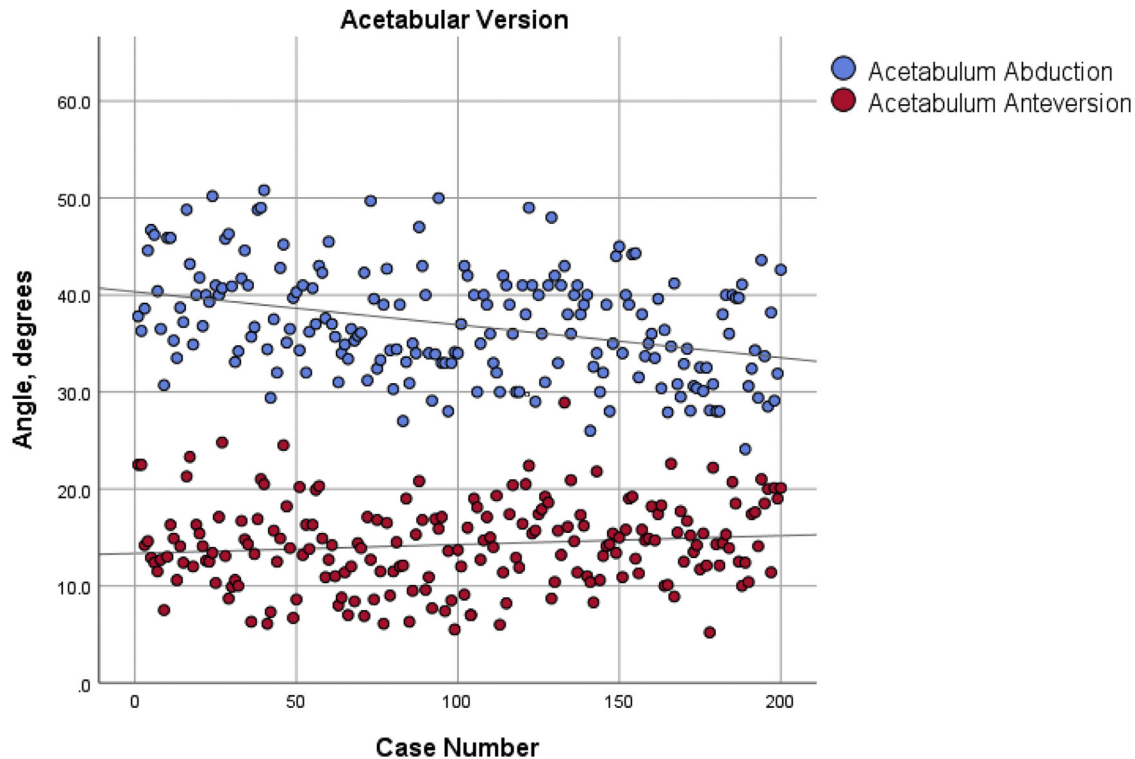
Acetabular Version

Figure 3. Acetabular component version in consecutive primary total hip arthroplasty using anterior approach.

pain with resolution of symptoms and signs of radiographic healing at 1 year postoperatively. Twelve patients were transfused postoperatively, 5 in the first 100 cases and 7 in the second ($P = .767$). In addition, urinary retention, hypotension, hematoma formation, agitation, hyponatremia, and atrial fibrillation were recorded leading to a 13% hospital complication rate for the first 100 cases and 7% for the second 100 ($P = .238$).

There were 5 surgical site infections in the first 100 cases and 6 in the second 100 cases ($P = 1.000$). All in the first group and 4 in the second group were superficial and successfully treated with local wound care. No patients in the first 100 cases, but 2 patients in the second 100, required readmission and reoperation. The first was readmitted 1 month postoperatively for a superficial irrigation and debridement, treated for 6 weeks with vancomycin, and had resolution of symptoms. The second patient was readmitted 1 week postoperatively with fevers, chills, and increasingly painful ambulation and was found to meet sepsis criteria (fever, leukocytosis, tachycardia, and an acute kidney injury) with bacteremia confirmed by cultures growing *Streptococcus dysgalactiae*. The patient underwent irrigation and debridement and liner exchange and was placed on ceftriaxone for 6 weeks and then amoxicillin for 2 months leading to resolution of symptoms. There were 6 readmissions within the cases series (3 in the first 100, 3 in the second 100). In the first group, one readmission was for a deep venous thrombosis, which was treated with anticoagulation without subsequent complication, and 2 other patients were readmitted to the medical service for atrial fibrillation. In the second group, the 2 previously mentioned patients with infections were readmitted, and a patient presented with chest pain 1 month postoperatively. The patient was found to have a pulmonary embolism and was treated with 6 months of anticoagulation. Finally, there were no postoperative dislocations in the case series and no fractures requiring change in management.

There was a difference in prevalence LFCN neuropraxia in both the first and second 100 cases (41 vs 9%, $P < .001$; Table 1) and the

first and last 50 cases (54 vs 10%, $P < .001$; Table 2). Patients reported paresthesias and had a duration of symptoms varying from 2 to 9 months.

Discussion

The DAA is an effective surgical option for THA that provides the potential for decreased postoperative pain, improved early functional outcomes, and shorter hospital stay. While previous studies have shown increased complications initially after adopting this approach, this study found that fellowship training can significantly reduce the incidence of complications over the first 100 cases. Over the first 200 cases in practice, there were significant differences in operative time, acetabular abduction and anteversion, and LFCN neuropraxia, but not estimated blood loss, transfusion rates, LOS, discharge disposition, or other postoperative complications. All but 2 of the 11 infections were superficial that were treated with local wound care and antibiotics. In addition, these patients were able to be frequently discharged home with minimal readmissions. Hospital LOS, blood loss, and surgical time trended but did not reach statistical significance among the groups. Although surgical time decreased with increasing cases, large variability was still found in the later cases. This may indicate secondary factors, independent from surgeon ability, were also impacting the surgical time. Finally, patients staying 5 days in the hospital or longer, deemed prolonged LOS, were more prevalent in the earlier cases. In consideration of the short-term benefits DAA can provide, further evaluation with larger data collection may help account for variations in institutional policies or operating surgeon schedules.

There were differences in LFCN neuropraxia and acetabular cup abduction angles between the first 100 and second 100 cases. However, the decrease in LCFN may be partially attributed to changes in patient reporting and surgical interview techniques. Improvements in tissue tension and retractor positioning may influence the rate of neuropraxia. In addition, improvements to

surgical technique leading to decreases in operative time may also contribute to a decrease in LFCN traction time. Furthermore, these differences did not alter the postoperative course of the patients. Next, while there was a reduction in acetabular abduction angle from 38.3 to 35.5 degrees, both outcomes fall well within acceptable positioning as described by Lewinnek et al. [26]. Also, while statistical differences in acetabular anteversion and abduction were found among the groups, these did not reflect direct clinical differences. Through postgraduate medical education featuring training in the DAA, we found a significant reduction in the learning curve required in the first 200 cases in a surgeon's practice.

The results of this analysis were consistent with other studies looking at the safety of performing the DAA within the learning curve. Schwartz et al. performed a retrospective analysis of consecutive primary THAs during a single-surgeon's transition period from posterior approach to DAA [8]. When compared to the previous 201 posterior approaches, the surgeon's first 211 DAA cases showed no differences in readmission (2.84 vs 2.49%, $P =$ .823), complications (6.16 vs 3.48%, $P =$ .206), or revisions (1.90 vs 2.99%, $P =$ .535). The analysis argued that transition to the DAA is safe and that it is possible to reduce the learning curve in a high-volume practice [8]. In addition, Free et al. retrospectively review 93 DAA THAs among 3 surgeons within their learning curve period (more than 15 but less than 100 cases DAA performed) [3]. In comparison to their prior 166 cases, the DAA showed a shorter LOS and higher rate of discharge home without any intraoperative fractures [3]. Similar to Schwartz et al., the authors concluded that the DAA can be safely adopted within the learning curve period. However, in both studies, surgeries were performed by experienced arthroplasty surgeons, who adopted the DAA after a combination of courses and observations. In contrast, our study evaluates the effect of postgraduate medical education in fellowship on the learning curve.

The incorporation of the learning curve in training has been shown in prior studies, within orthopedics and in other surgical specialties [28-30]. While Unwin and Thomas had previously found increased dislocation rates in junior registrars performing hemi-arthroplasties, Palan et al. was able to find good results with supervised training of registrars [31,32]. In the analysis of 967 THAs performed by either trainees or surgical consultants, Pelan et al. found no differences in Oxford Hip Scores, complication rates, or revisions between trainers or trainees. Operative times were higher in the trainee group, attributed to the learning curve observed in registrars. Senior trainees did show significantly higher Oxford Hip Scores at 5 years than junior trainees, possibly indicating some improvements as training progresses. However, there were no differences in dislocation or revision rate between senior and junior trainees [31]. This analysis gives credence to both the safety and effectiveness of incorporating a learning curve into fellowship training.

Conversely, Hartford and Bellino reviewed the first 500 DAA cases by a single surgeon and found the major complication rate decreased (5 to 2%) while the fracture rate decreased (9 to 2%) [19]. The group identified a significant decrease in complications and improvement in overall outcomes after the first 100 cases in the DAA [19]. While this study showed a significant learning curve within the first 200 cases, these cases were performed after cadaveric courses and assisting another DAA surgeon once per week for 6 months. Therefore, the learning curve could not be incorporated into a more formal training program and occurred over the first 200 cases in the analysis.

This study is not without its limitations. This is a single-surgeon study, thus limiting the data to one surgeon's experience and potentially limiting the generalizability of the study. The study also focused on a small group of patients; 200 patients with one to 2 years of clinical follow-up. However, prior studies demonstrated a learning curve up to 50 to 100 patients, which was less than our sample size. When considering LOS, there may be variations in the recording of data by different ancillary staff, and this may introduce bias. Similarly, error in data collection may be present in the radiographic measurements of acetabular anteversion and abduction. While the authors attempted to reduce error by re-evaluating large measurement discrepancies between assessors, the difference in acetabular positioning between groups may still be impacted. Next, while femoral exposure is often one of the more challenging aspects of this approach, no analysis of the femoral component was performed. The effect of the learning curve on femoral component positioning may be an area of future investigation. Finally, this study did not collect patient-reported outcome measures, which could provide further information on the impact of fellowship training on patient's postoperative course. The influence of fellowship training on these outcome measures would be a beneficial analysis and is an interesting direction for future studies.

Conclusions

The technical challenges and learning curve of the approach have brought the safety of the approach into question, especially early in a surgeon's practice. The results of this study indicate that the incorporation of the anterior approach into fellowship training may reduce hospital complications, fractures, dislocations, subsidence, and reoperation in surgeons performing THAs using the DAA. As this approach becomes more widespread, it may be beneficial for training programs to incorporate the DAA into postgraduate medical education. More multisurgeon studies need to be performed to demonstrate the impact of fellowship training on postoperative outcomes.

Conflict of interests

The authors declare there are no conflicts of interest.

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