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Differences in Outcomes during the Learning Curve of the Anterior Approach Compared to Posterior and Lateral Approaches of Total Hip Arthroplasty: A Retrospective Matched Cohort Study

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Abstract

Background: Multiple approaches to Total Hip Arthroplasty (THA) exist including but not limited to the Lateral Approach (LA), Posterior Approach (PA), and Anterior Approach (AA). Interest within the Anterior Approach (AA) to is increasing but safety and whether benefits exist during the learning curve are constantly questioned.

Purpose: The purpose of this study was to compare outcomes in primary total hip arthroplasties performed through AA during the learning curve compared to LA and PA.

Methods: Using a retrospective, multi-center matched study design and exceeding the necessary sample size calculation, 115 patients that underwent AA were matched to 230 LA and 230 PA. Patients were matched for age (p=0.99), gender (p=0.999), medical comorbidities (p=0.410), and BMI (p=0.983). Outcomes including significant medical and mechanical events, length of stay, discharge destination, 30-day readmission rate, transfusion rates, surgical time and narcotic use were analyzed.

Results: A 30-day readmission rate (p=0.778) and medical events (p=0.225) were not statistically significant. The average surgical time for the AA was 17.99 min (p<0.001) longer than the average combined time for LA and PA. Statistically significant fewer mechanical complications including dislocation (p=0.011), LOS (p<0.001), more patients discharged directly home (p=0.016) and fewer blood transfusion (p=0.002) with AA compared to LA and PA. Average per hour morphine equivalent use of the first three post-operative days was significantly less for AA when compared to LA (p=0.01) and PA (p=0.02).

Conclusion: As expected, the AA has an increase in surgical time compared to other approaches during the learning curve without a change in the number of cases per day. However, the AA has fewer mechanical complications, shorter acute LOS and total LOS, has more patients being discharged directly home and fewer blood transfusions. Patients undergoing AA also have significant less pain and therefore require less post-operative narcotics. Overall, we found the learning curve of the anterior approach to be safe.

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Introduction

Osteoarthritis disables about 10% of people over 60 years of age, compromises the quality of life of over 20 million Americans, and costs the United States economy more than $60 billion per year [1]. Total Hip Arthroplasty (THA) is the most effective intervention to relieve pain, increase range of motion and improve quality of life for end stage arthritis [2-7]. Because of the success, the rates and cost burden of THA are exponentially increasing.

The 2014 Canadian Joint Replacement Registry annual report estimated 104,855 hospitalizations for all hip and knee replacements from 2012 to 2013. Of this, 47,137 were hospitalizations for THA. This represents a five-year increase of 16.5% [8]. In the US, the demand for THA increased by 52% between 2000 to 2006 [9]. By 2030, it is expected that demand for THA will increase by 174% compared to demand in 2005 [10]. This creates a major financial burden on the healthcare system and consequently pushing surgeons to find ways to decrease costs while maintaining, if not improving, patient outcomes following THA.

Worldwide, the most commonly used approaches to THA are the Posterior Approach (PA) and the Lateral Approach (LA) with approximately 45% of surgeons using the PA and 42% using the LA. Meanwhile interest in the AA is slowly increasing with 10% using the AA [10-12]. However, these number continue to fluctuate as new data becomes available and with adoption of novel techniques [10-12].

Despite the immense increase in function from THA, post-operative functional restrictions are suggested due to fears of possible complications. Specifically, dislocations limp and pain. A dislocation risk are highest in the PA and has been reported in up to 4.46% of primary THA but can be reduced with careful repair [13-19]. It is because of the fear of dislocation hip precautions; including limited forward flexion and hip adduction exist for both PA and LA [12,17-20]. Efforts on decreasing dislocation enticed surgeons to use the LA [21-24].

The LA has a dislocation rate between 1% to 2% but reported up to 3.3% [25-29]. Despite the reduced dislocation risk of the LA, disruption of the abductor tendon can compromise post-operative rehabilitation. This leads to development of a post-operative limp which is reported in 4% to 20.4% of patients [25,27,28,30-33]. The rate of post-operative limp persists approximately 3 months at which time resolution usually occurs, however in a small portion of patients, this can persist [34].

The AA is an inter-muscular and inter-nervous approach which preserves the abductors and short external rotators opposed to the LA and PA respectively [26,35-41]. Curiosity is slowly increasing due to the reported earlier functional recovery and a low dislocation rate [11,28,31,36,38,40,42-44]. The AA has the lowest risk of dislocation between 0% to 0.96% [11,28,38,40,42-44]. Because of this extremely low dislocation rate, no restrictions are placed upon patients post-operatively [45]. There is growing evidence that the AA leads to shorter Length of Stay (LOS) [4,39,46-53], higher rate of direct home discharges [30,36,39,44,53-56], less post-operative pain [4,46,47,50,53,57,58] improved gait and function [3,4,6,7,34,37,44,47,50,53,54,56,58-61] and low dislocation rate [4,12,28,31,37,38,40,42-44,61-64]. However, the value of the AA is questioned when considering the possible complications during the learning curve.

The purpose of this study is to assess in patients with unilateral hip osteoarthritis, is the AA during the learning curve compared to LA and PA safe when assessing LOS, number of patients being discharged directly home, acute in-hospital mechanical and medical adverse events, transfusion rates, surgical time as well as pain post-operatively?

Materials and Methods

Using the affiliated institute database between 2014 to 2017, we included those who underwent primary, unilateral, THA through AA, LA or PA. Patients were excluded if they underwent bilateral THA, hip resurfacing or if undergoing surgery for revisions, infections, congenital deformity or periprosthetic fracture.

Nine outcomes measures were analyzed: Significant medical events (myocardial infarction, pulmonary embolus, deep vein thrombosis, cardiovascular accidents, ileus, gastrointestinal bleeding and pneumonia), mechanical events (mechanical complications of the prosthesis, intra-operative fracture, post-operative fracture and dislocation), narcotic use, acute LOS (duration in days from patient admittance to hospital to discharge from first acute hospital) and total LOS (acute LOS time spent in rehabilitation facility), rate of direct home discharge, 30-day readmission rates, transfusion rates and surgical times. Rate of in-hospital complications (medical and mechanical) included complications, which arose during anesthesia, surgical procedure and acute in-hospital recovery period. 115 AA patients were matched to 230 LA and 230 PA. A single surgeon performed all AA during the learning curve of the procedure while the LA was performed by eight surgeons and PA was performed by five surgeons. AA was performed using the Hueter interval in the supine position. The radiolucent orthopedic table and image intensifier was used to verify cup position, leg length and offset during the AA.

All patients received the same provincial post-operative pain management and rehabilitation protocol while in hospital. The majority (67%) of surgeries were performed with spinal anesthetic while the remaining (33%) were performed by GA. Intravenous tranexamic acid was used in all patients. Blood transfusions were only administered in severely symptomatic patients with hemoglobin below 70 g/L. Patients were discharged home once pain was controlled and passed rehabilitation-accepted benchmarks. If the rehabilitation team deemed the patient unsafe for discharge home, arrangements were made for a transfer to a rehabilitation facility. The total in-hospital narcotic usage until the time of discharge was collected. All narcotic use was converted into morphine equivalents and was analyzed both in total amount of narcotic usage and a rate of narcotic consumption per hour during the acute in-hospital stay.

Calculation of sample size for comparing two means with a 2-sided test using a type I error rate of 0.05 and power of 0.80. Using Narcotic consumption values for post-operative day 0 and a 1:2 ratio anterior to posterior approaches with morphine equivalent for anterior approach 32.2 mg and posterior approach 41.4 mg with standard deviation for anterior approach of 26.2 mg [58]. This gives a sample size for anterior approach of 95 and for the posterior approach using the enrollment ratio of 1:2, of 190 patients. Our chosen sample size, aimed to the required numbers to reduce bias and strengthen results. Therefore, we chose to perform a 1:2 ratio of 115 AA group and 230 PA and 230 LA. Due to the immense negative effects of narcotics, any amount of reduction is clinically relevant. However to remain conservative, we deemed a 30% reduction in narcotics during the inpatient hospital stay to be set at the level of the minimally clinically significant change in the outcome.

We used propensity score nearest neighbor matching to select LA and PA groups that were similar to our AA group for the patient characteristics of age (p=0.99), gender (p=0.999), number of pre-surgery risk factors (p=0.410), and Body Mass Index (BMI) (p=0.983) (Table 1). Propensity score matching is a validated technique that allows creation of comparable groups for statistical analysis [65].

Table 1: Demographic data for 575 patients undergoing Total Hips Arthroplasty (THA).

		AA N (%)	LA N (%)	PA N (%)	Total N (%)	p-value
Gender	Male	62 (54.9)	124 (54.9)	124 (54.9)	310 (54.9)	0.999*
	Female	53 (46.1)	106 (46.1)	106 (46.1)	265 (46.1)	
N. of pre-surgery - risk factors	0	40 (34.8)	84(36.5)	73 (31.7)	197 (34.2)	0.410*
	1	48 (41.7)	84(36.5)	83 (36.1)	215 (37.4)	
	2	13 (11.3)	40 (17.4)	47 (20.4)	100 (17.4)	
	3	9 (7.8)	15 (6.52)	18 (7.8)	42 (7.3)	
	4	5 (4.4)	6 (2.6)	5 (2.17)	16 (2.8)	
	5	0 (0)	1 (0.4)	4 (1.7)	5 (0.9)	
		Mean ± Std. Dev	Mean ± Std. Dev	Mean ± Std. Dev	Mean ± Std. Dev	
BMI	(kg/m^2)	29.36 ± 5.70	29.37 ± 5.16	29.44 ± 5.34	29.40 ± 5.34	0.474**
Age at admission	Years	66.38 ± 10.57	66.46 ± 10.59	66.42 ± 10.49	66.43 ± 10.53	0.998

* Chi-square test
**One-way ANOVA test

The provincial Hip and Knee Clinical Committee selected 11 risk factors that were most relevant in arthroplasty which includes cardiac illness, chronic pulmonary condition, cancer, and stroke, history of deep vein thrombosis or pulmonary embolus, chronic hepatic condition, chronic renal condition, diabetes with complications, obesity, dementia, and moderate to severe mental illness. The resulting set of 11 pre-surgery risks was compared to Charlson Comorbidity Index and Elixhauser Index and was found to be superior in capturing variability in arthroplasty surgical outcomes (LOS, readmission, inpatient complication, change in physical function, and death).

Continuous variables (age, BMI and narcotic usage) were summarized as a mean with Standard Deviation (SD); categorical variables (pre-surgery risk factor, gender, discharge home and transfusion) were expressed as percentages. Adverse events (medical event and mechanical event) were calculated as a rate per 100.

Chi-Square test was used to test for significance in the comparison of categorical outcomes. T-test was used to test for significance in the comparison of continuous values for 2 study groups and one-way ANOVA test was used to test for significance in the comparison of continuous values for 3 groups.

Due to distributions of acute LOS, total LOS, cut-close time and total surgical time are skewed as the standard deviations are larger than the means; the medians were presented with the means and standard deviations. K-sample-equality-of-median non-parametric test was explored to compare those values for 3 study groups (Table 2).

All statistical analyses were performed with STATA version 13 (STATA, College Station, Tex) software. There was no external source of funding for this study. All the data was de-identified by affiliated institute according to the provincial health authority's de-identification standards to allow for matching. This study was approved by the University Conjoint Health Research Ethics Board (CHREB) and by provincial health services research department to access patient specific data.

Results

A total of 575 patients were included in this study with 115 in the AA group and 230 in each of the LA and PA groups. Demographic information (gender, number of risk factors, BMI and age) are summarized in Table 1.

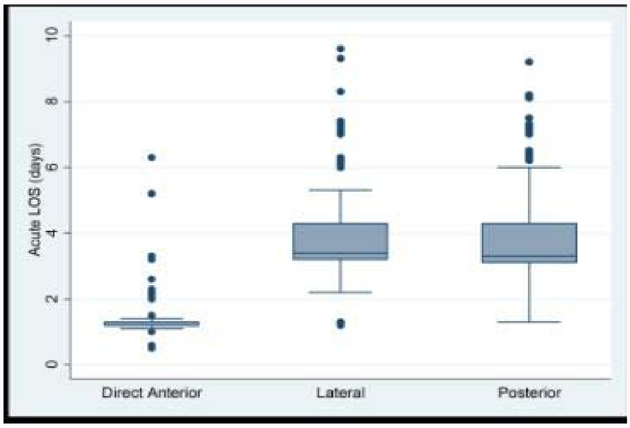

Figure 1: Summary of acute length of stay. Summary of acute in-hospital Length of Stay (LOS) with standard deviation.

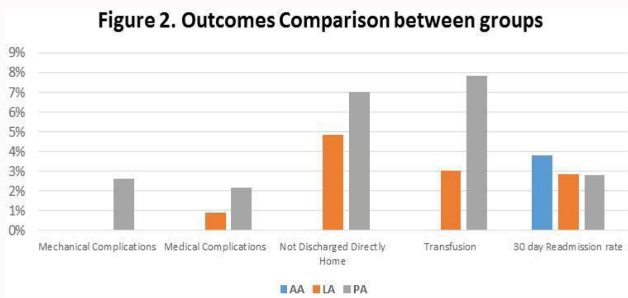

Figure 2: Summary of outcome values. Summary of comparison results between the Anterior Approach (AA), the Lateral Approach (LA) and the Posterior Approach (PA).

Median (and mean) acute LOS in days was 1.3 (1.41 ± 0.73), 3.4 (4.18 ± 1.88) and 3.3 (4.44 ± 3.43) for AA, LA and PA respectively (p<0.001) (Table 2 and Figure 1). All patients from the AA group were discharged directly home. Eleven (4.82%) LA and 16 (7.02%) PA patients required transfer from hospital to a rehabilitation facility prior to safe discharge home (p=0.016) (Table 2 and Figure 2). Total LOS was significantly greater (p<0.001) in both LA (5.06 ± 5.85) and PA (6.65 ± 11.82) groups compared to AA group (1.41 ± 0.73) (Table 2).

Total morphine consumption during the acute inpatient hospital

Table 2: Results of comparison of DAA *vs.* LA and PA.

		AA N (%)	LA N (%)	PA N (%)	Total N (%)	p-value
Medical Events	# of events	0 (0)	2 (0.09)	5 (2.2)	7 (1.2)	0.225*
Mechanical Events	# of events	0 (0)	0 (0)	6 (2.6)	6 (1.0)	0.011*
Re-admit 30 days	# of events	4 (3.8)	6 (2.8)	6 (2.8)	16 (3.02)	0.778*
DC home	# of patients DC directly home	0 (0)	11 (4.8)	16 (7.0)	27 (4.7)	0.016*
Transfusions	# of transfusions	0 (0)	7 (3.0)	18 (7.8)	25 (4.35)	0.002
* Chi-square test						
		Median	Median	Median	Median	
		(Mean ± Std. Dev)	(Mean ± Std. Dev)	(Mean ± Std. Dev)	(Mean ± Std. Dev)	
Acute LOS	Days	1.3 (1.41 ± 0.73)	3.4 (4.18 ± 1.88)	3.3 (4.44 ± 3.43)	3.2 (3.73 ± 2.76)	**<0.001
Total LOS	Days	1.3 (1.41 ± 0.73)	3.4 (5.06 ± 5.85)	3.3 (6.65 ± 11.82)	3.2 (4.97 ± 8.56)	**<0.001
Cut-Close OR Time	Minutes	90 (96.21 ± 22.51)	73.5 (75.88 ± 26.13)	78 (80.57 ± 22.84)	79 (81.82 ± 25.25)	**<0.001
Total OR Time	Minutes	130 (133.13 ± 24.00)	115 (117.80 ± 28.52)	122 (126.61 ± 29.66)	121 (124.39 ± 28.72)	**<0.001

** K-sample-equality-of-median- non-parametric test

Table 3: The intensive morphine (morphine dose equivalents per hour) comparison between approaches.

Group	N. of patients	Mean ± STD (mg)	p-value
Whole period			
AA	74	1.48 ± 0.95	
LA	219	1.92 ± 0.96	0.01*
PA	218	1.88 ± 1.41	0.02*
Day 1			
AA	74	1.75 ± 0.97	
LA	219	2.96 ± 1.30	<0.001*
PA	218	2.98 ± 1.64	<0.001*
Day 2			
AA	7	0.87 ± 0.49	
LA	196	1.55 ± 0.90	
PA	182	1.61 ± 1.54	
Day 3			
AA	4	1.11 ± 0.70	
LA	161	1.32 ± 0.88	
PA	136	1.29 ± 1.53	

*Compared with anterior approach

Table 4: Total morphine equivalent consumption during the acute hospital stay.

	Minimum	Maximum	Mean	Std. Deviation
AA	3	202	36.64	35.761
Lateral	6	720	168.47	104.197

stay was 37 ± 36 mg for AA, 168 ± 104 mg for LA and 145 ± 112 mg for PA (p<0.001) (Table 3). Unique to our study, per hour morphine consumption was analyzed for the first 3 Post-Operative Days (POD). The patients in the AA group required 1.75 ± 0.97 mg/hr of morphine equivalents while the LA group required 2.96 ± 1.30 mg/hr and the PA group required 2.98 ± 1.64 mg/hr on POD-1 (Table 4). When individually compared to LA and PA groups, the AA group required statistically less narcotic on POD-1 p<0.001. On POD-2, the AA group required 0.87 ± 0.49 mg/hr compared to 1.55 ± 0.90 mg/hr in the LA group and 1.61 ± 1.54 mg/hr in the PA group (Table 4).

Of the 115 AA and 230 LA THAs, there were no mechanical complications prior to discharge home (Table 2 and Figure 2). There

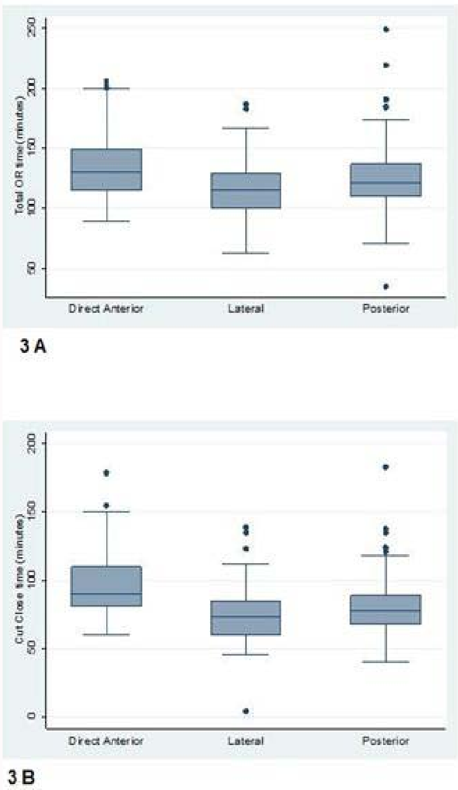

Figure 3: Summary of OR Times. Summary of mean cut-close and total OR time with standard deviation.
AA: Anterior Approach; LA: Lateral Approach; PA: Posterior Approach.

were 6 (2.61%) mechanical complication in PA group, which was statistically significant (p=0.011). There were no medical events in the AA group, 2 (0.87%) in LA and 5 (2.17%) in PA. However, this did not reach statistical significance (p=0.183) (Table 2 and Figure 2). No patients in the AA group required blood transfusion, while 7 patients (3.04%) in LA and 18 (7.83%) in PA (p=0.002) required transfusions. There were no statistically significant differences (p=0.778) in 30-day readmission rates with 4 (3.77%), 6 (2.83%) and 6 (2.83%) in the AA, LA and PA groups respectively (Table 2 and Figure 2).

The operating room time was divided into 2 categories (Table 2).

The first was categorized as the cut-close time which we defined as the time from skin incision to skin closure. Second was the total time the patient was in the operating room until being transfer to the post anesthetic recovery room. The median (and mean) cut-close time in minutes for the AA, LA and PA are 90 (96.2 ± 22.5), 73.5 (75.9 ± 26.1) and 78 (80.6 ± 22.8) (p<0.001) (Table 2, Figure 3). This signifies that the mean AA cut-close time for the AA is 20.3 min longer than for the LA and 15.6 min longer than the PA. These differences decreased to 15.3 min and 6.5 min for LA and PA respectively for the total OR time (p<0.001) (Table 2).

Discussion

In this study, we compared early outcomes of primary, unilateral, uncomplicated THA performed during the learning curve of the AA compared to the LA and PA using a matched retrospective cohort study design. Our data supports the slowly growing evidence that the AA leads to shorter LOS [4,39,46-53], higher rate of patient being discharge directly home [4,44,53-56], less post-operative pain [4,47,48,50,53,57,58], and low dislocation rate [4,12,28,31,37,38,40,42-44,61-64]. However, as expected, does show an increased surgical time during the learning curve.

LOS has a large role in cost savings. In our study, acute LOS was on average 2.77 days longer for the LA and 3.03 days longer for the PA compared to the AA. This difference jumped to 3.65 days and 5.24 days when assessing total LOS which included whether the patient required a rehabilitation admission prior to discharge home. These findings coincide with previous publications. Martin et al. [56], retrospectively compared 41 anterior and 47 posterior approaches and demonstrated a mean hospital stay of 2.9 days for the AA and 4 days for the PA (p=0.001) and after multivariate regression, the AA remained a significant predictor of early discharge (p=0.009) [56]. Multiple other studies have assessed LOS after THA and have demonstrated a LOS ranging between 0.6 and 3.2 days shorter for the AA than other approaches [46,47,49,50,52,53,66,67]. Despite the known decreasing trend of admission lengths of all THA patients, even more than what has been shown in this study, the pertinent finding of this study highlight that the AA patient do seem to discharge sooner than other approaches.

All the patients in the AA group were discharged directly home without the need for transfer to a rehabilitation facility. Eleven (4.82%) and 16 (7.02%) patients in LA and PA group respectively required transfer to a rehabilitation facility before they were deemed safe to return home. This is fairly consistent in the literature with multiple studies demonstrating a higher direct home discharge rate in the AA compared to other approaches [44,53-55,66]. Our study had a low 30-day readmission rate in all the groups that was not statistically significant. The AA had 4 (3.77%), while LA and PA each had 6 (2.83%) 30-day readmissions (p=0.778). Our results are supported by Malek et al. [56], and Maratt et al. [68]. Who also did not demonstrate a statistically significant difference in readmission rates between AA and PA [56,68].

There is significant diversity in the literature when assessing transfusion rates for various approaches. In our study, we had a 0%, 3.04%, and 7.83% transfusion rates for AA, LA and PA respectively (p=0.002). Our results are supported by Van Den Eeden et al. [48], who in a study of 378 patients also had zero patients requiring a blood transfusion for primary THA *via* AA [48]. Some studies have demonstrated a lower transfusion rate in the AA compared to other approaches [3,57,66] while others have shown no difference between the approaches [6,46,54,56,67,68] and others demonstrating higher transfusion rates in the AA, especially during the learning curve [44,60]. Ultimately, a systematic review and meta-analysis of 12 articles did not show a difference in transfusion rates between the AA and the LA (RR 0.78, 95% CI 0.60-1.02, P=0.07) [52].

Across all three groups, mechanical complications including fracture and dislocation were low. There were no mechanical complications in both the AA and LA groups, however the PA group had 2.61% (6 of 230) event rate (p=0.011). There is concern for an increased risk of femur fracture using the AA given a greater difficulty with femoral exposure and broaching especially during the learning curve [69], however multiple studies support a low fracture rate with AA [6,28,31,37,38,44,46,54,56-61,63,64,67,68,70,71]. This low femoral fracture rate of the AA is similar to that of the PA and LA is supported by two systematic reviews and meta-analyses by Higgins et al. [4] and Yue et al. [52]. Dislocation remains a major post-operative fear [45,72,73]. As did our study, there is an abundance of evidence to suggest a very low dislocation rate in the AA with the rate ranging from 0% to 0.96% [28,31,37,40,43,44,63,64].

Pain has often been the limiting factor on LOS and post-operative patient comfort. Pain is not only a function of the necessary bony work, but also arises from the soft tissue dissection. Both the LA and PA are not considered muscle sparing *vs.* the AA being a muscle sparing intermuscular, internervous approach [26,35-41]. Our study demonstrated a significant decrease in the mean total narcotic usage during the acute inpatient hospital stay (36.64 mg AA, 168.47 mg LA, 145.49 mg PA, p<0.001) (Table 4). This is consistent with multiple studies that have assessed overall narcotic use and demonstrated AA requires less post-operative narcotics [4,46,47,50,53,57,58,66]. As an example, Goebel et al compared 200 patients (100 AA, 100 LA). They demonstrated patients undergoing the AA had significantly less narcotic utilization (p=0.005) [50].

We assumed that patient's level of comfort would reflect in the amount of narcotic usage. In other words, if patients are in pain, they will request narcotics. When looking at total narcotic consumption, we found the significant reduction was not only statistically significant, but also far exceeded our 30% threshold for clinically meaningful difference in outcome (over 400% reduction). Furthermore, we used narcotic consumption as a surrogate objective marker to understand the degree of patient comfort per hour post-operatively. This could only be accurately calculated for POD-1, as by POD-2, only 7 patients from the AA group remained in hospital. Patients that had a THA *via* AA had significantly less per hour narcotic use, therefore less pain and more comfortable than patients undergoing THA *via* LA and PA. To our knowledge, this is the first study to have analyzed narcotic use, using this novel perspective, on a per hour basis during the acute hospital stay to represent an objective measure of patient's level of pain and overall level of comfort.

Multiple studies have demonstrated increased OR time use for the AA compared to other approaches especially during the learning curve. We demonstrated that the average AA used an extra 18 min of cut-close time but only 11 min of extra total OR time in comparison to the combined time of the LA and PA. We attribute this to the shorter set-up time of the AA as patients remain supine *vs.* lateral decubitus position. Some studies have demonstrated a longer OR time in AA ranging between 20 min to 25 min [46,49,56]. However, this difference seem to be related to the learning curve of the approach as multiple studies do not show a difference in OR time after the learning curve [53,54,60,70,71].

Limitations of our study include its retrospective study design and we assumed morphine equivalent narcotic consumption could be used as a surrogate marker for patient level of comfort. However, we felt we were able to overcome these obstacles with this study's strength being a large, well-powered, matched cohort study. Furthermore, our sample size calculation was based on narcotic consumption comparison on post-operative day zero from previous study. This sample size exceeds the sample size needed to detect differences in narcotic consumption difference, LOS, transfusion, discharge and OR time; it does not have adequate power to detect difference in other specific adverse event rates such as deep venous thrombosis, pulmonary embolism and deep infection. Finally, there are multiple methods described to perform the AA. Some include the method used in this study in the supine position on an orthopedic table and using image intensifier. However, other methods have been used including lateral position on a standard table, or supine on a standard table, and some do not use image intensifier. Further research is necessary to understand the most reproducible method to perform the AA. Ultimately, a well-designed prospective randomized control trial comparing AA to PA and LA is necessary.

Conclusion

Despite an increase in surgical time, the AA patients' during the learning curve seemed to have has less pain, shorter acute and total LOS, more patients being discharged directly home, fewer significant mechanical complications and fewer blood transfusions.

Unique to our study, we were able to use the amount of narcotic consumption per hour, or rate, as a surrogate marker for level of patient comfort post-operatively. To our knowledge, we were the first group to show a statistically significant decrease in morphine consumption per hour post THA and therefore objectively quantifying an increased level of comfort per hour after the AA *vs.* LA and PA approaches.

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