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General

Compared learning curves of the direct anterior and anterolateral approach for minimally invasive hip replacement

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Minimally invasive hip arthroplasty becomes increasingly popular. It is technically challenging and the approaches used are associated with a considerable learning curve. This nurtures concerns regarding patient safety, surgical training, and cost effectiveness. Consequently, we initiated a study comparing the learning curves of a supervised trainee surgeon utilizing both the anterolateral and direct anterior approach (DAA) when introduced to minimally invasive hip replacement surgery. Outcome measurements included the Harris hip score (HHS), cup inclination and anteversion, offset and leg length, stem placement, surgical time and complications. Time from incision to suture decreased significantly over time but did not differ between both groups. The functional outcomes (HHS) after six weeks and three months were comparable (p=0.069 and 0.557) and within the expected range equalling 90.3 (anterior) and 89.2 (anterolateral) points. With both approaches safe component placement was readily achieved. Both offset and leg length, however, were reconstructed more reliably with the DAA (p=0.02 and 0.001). A higher rate of dislocations was seen with the anterior, more perioperative infections with the anterolateral approach. We suggest that supervision by an experienced surgeon favourably influences the learning curves for both the minimally invasive DAA and anterolateral approach and conclude that the greatest improvement is seen within the first 60 cases.

INTRODUCTION

Hip replacement surgery in general is a very beneficial treatment for patients affected by osteoarthritis.[1] Over time, technical refinements have positively influenced the efficiency of total hip arthroplasty (THA). The increasingly demanded soft tissue protecting minimally invasive approaches (MIS) include the direct anterior (DAA) and the anterolateral approach (ALMI). Reported MIS benefits include lower rates of perioperative anaemia, lower pain scores, and quicker mobilization.[2] The DAA in particular was reported to result in better functional outcomes compared to other approaches.[3] The use of MIS approaches is technically challenging and complication rates may be higher, especially among surgeons newly introduced to these techniques. This has nurtured discussions regarding learning curves.[4] Identifying these curves has considerable implications regarding patient safety, surgical training, and cost effectiveness.

Consequently, we aimed to compare the learning curves associated with the minimally invasive DAA in supine or ALMI in lateral recumbent position. Outcome measures included surgical time, radiological results, complication rates and hip functionality.

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METHODS

The current retrospective study was assessed by the institutional review board and formal consent was obtained from all participants. The study was designed to determine learning curve differences of the minimally invasive DAA in supine position[5] and the anterolateral approach in lateral recumbency.[6] Both the DAA and ALMI are routinely used approaches for THA in our clinic.

The required number of patients for each group was estimated to be 81 (G*Power 3) applying a two-sample t-test of independent variables (α=0.05, (1-β)=0.09, effect size 0.5). The study was powered to detect an eight minute difference of surgical time with an assumed standard deviation of 15.

Expecting 19% off all patients to have incomplete records, we decided to include a total of 100 consecutive individuals in each group. Surgeries were performed between February 2014 and September 2018 and consisted of consecutive series of hip replacement using the AMIS and ALMI.

In the DAA group the data sets of five patients were incomplete. Twelve data sets had to be excluded from the anterolateral cohort. Incomplete data sets were not considered for further analysis. A single, consultant-supervised trainee surgeon newly introduced to both techniques performed all surgeries.

We included patients with primary osteoarthritis or femoral neck fractures planned for hip replacement surgery. All patients had to meet the following criteria: The defined age range was 40-95. Severely obese patients (BMI > 35 kg/m^2) and/or patients with an ASA score $\geq$ 4 (American Society of Anesthesiologists) were not considered. We also excluded patients with dysplastic hips, inborn deformities, and patients with a past osteotomy of the pelvis or proximal femur.

The selected implants are all commercially available. They included Allofit cups, the Avenir (cementless), the Mueller straight (ZimmerBiomet) or AS Plus stem (Smith&Nephew, both cemented). In total, we accounted for 45 cemented stems in the DAA and 24 in the ALMI group.

Perioperatively, all patients received multimodal pain medication and were rapidly mobilized.

A qualified physician examined all patients enrolled prior to surgery as well as six and twelve weeks postoperatively.

Hip function was assessed utilizing the Harris hip score (HHS).[7]

Two independent observers evaluated radiographs of the pelvis (anterior-posterior, Lauenstein) to measure cup inclination, anteversion, stem orientation, offset and leg-length as describe previously.[8–10] Osseous implant integration was assessed.

At the time of follow-up, clinical examination was performed for all patients, respectively.

We analysed the collected data-sets for normal distribution (Kolmogorov-Smirnov-test, Shapiro-Wilk-test). In case of normal distribution, inter-group comparisons were performed with a two-tailed t-test, non-parametric data was assessed applying the Mann-Whitney-U test.

Within group comparisons over time were analysed using the non-parametric Friedman test. Post hoc analysis consisted of a Wilcoxon signed-rank test including Bonferroni adjustment. The data analysis software SPSS 19.0 was used (IBM, Ehningen, Germany), and the significance level set to 5%.

RESULTS

We performed 100 arthroplasties each using the minimally invasive DAA and anterolateral approach. This included 17 femoral neck fractures in the DAA and 12 femoral neck fractures in the anterolateral group. Beyond that, demographic base line parameters of the treatment groups did not show relevant differences (Table 1).

With both approaches time from incision to suture significantly decreased with growing surgical experience, it did not differ significantly between the two cohorts (Table 2, Figure 1A, B). No significant difference was found when comparing cemented and cementless THA.

The Harris hip scores confirmed the very good functional outcomes. With both approaches, the HHS after six and twelve weeks increased significantly ($p \leq 0.001$; p=0041, Table 3).

No significant difference between the two surgical approaches could be found for the overall HHS or any of its domains. Twelve weeks after surgery the HHS equalled 90.3 points with the DAA and 89.2 with the anterolateral approach (p=0.557) (Table 3).

Average cup inclination equalled 38.2° (SD 4.2) in the DAA group and 39.4° (SD 4.5) in the anterolateral group (Table 3). Cup anteversion was 15.8 degrees (SD 3.4) with the DAA and 16.4 (SD 4.9) with the ALMI approach, thus not differing significantly (p=1.00) (Table 4). Within the follow-up period, we did not see any signs of cup migration.

Offset reconstruction, presented in percent of the contralateral side, was achieved to 99.5% (SD 6.6) with the DAA while only 95.9% (SD 12.9) were stated for the ALMI, thus differing significantly (p=0.02) (Table 4). Previous studies have shown the non-existence of side-specific differences in relation to the femoral offset.[11]

Leg length showed an average shortening of 0.4 mm (SD 3.0) in the DAA group and an average lengthening of 1.28 mm (SD 4.4) in the ALMI group (p=0.001) (Table 4, Figure 1C).

In both groups, hip stems were positioned neutrally in 99% of all cases while 1% were assessed valgus. No varus stem alignment was observed.

With both approaches, all cementless implant components appeared well integrated into the surrounding bone.

We observed a number of peri- and postoperative adverse events with the direct anterior approach (Table 5, Figure 1 D): Two cases of lateral femoral cutaneous nerve (LFCN) impairment were noted. These neuropraxias were limited to simple dysesthesia without association of neuropathic pain or occurrence of neuromata. All LFCN deficits had resolved spontaneously at final follow-up. One deep

Table 1. Patient base line and parameters at final follow-up.

preoperative	**DAA**		**ALMI**		
		range		range	*p*-value
patients	100		100		
age (years)	70.4 (SD 9.6)	47-89	72.6 (SD 8.5)	48-93	0.21
female	63		59		0.18
Body Mass Index (BMI)[a]	28.4 (SD 3.3)		28.7 (SD 3.6)		0.87
final examination	**DAA**		**ALMI**		
		range		range	*p*-value
patients	95		88		
age (years)	71.5 (SD 9.1)	47-89	73.1 (SD 8.9)	48-93	0.23
female	60		48		0.16
Body Mass Index (BMI)[a]	28.4 (SD 3.3)		28.3 (SD 3.4)		0.84

SD: standard deviation, [a] Mann-Whitney-U test

Table 2. Time in minutes required for THA.

number of surgeries	time [m] (SD)		
	anterior	anterolateral	*p*-value
1-30	72.5 (15.8)	71.4 (15.4)	0.63
31-60	60.9 (11.27)	59.9 (12.2)	0.68
>60	55.0 (9.3)	54.2 (8.6)	0.74

SD: standard deviation

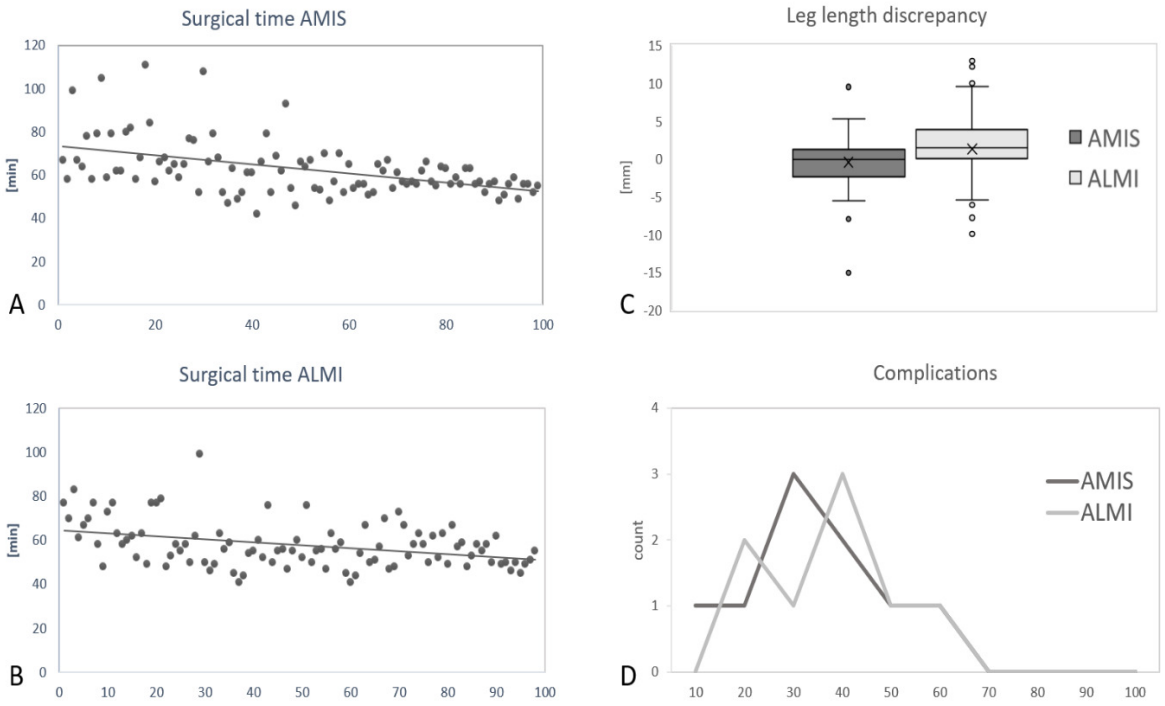

Figure 1. Scatter plots representing the time of incision to suture for the anterior (AMIS, A) and anterolateral (ALMI, B) approach. Box plot depicting the measured leg length discrepancies for AMIS and ALMI (C). Number of observed complications per ten hip arthroplasties (D).

Table 3. Time-dependent inter-group comparison of the HHS.

HHS	mean (SD)		95% CI		*p*-value
approach	anterior	anterolateral	anterior	anterolateral	
time points					
preoperative	53.2 (15.6)	54.1 (14.4)	50.7-57.1	49.5-56.8	0.278[a]
6 weeks	82.5 (11.7)	81.9 (12.1)	78.5-83.6	78.7-85.1	0.069[a]
3 months	90.3 (9.7)	89.2 (10.1)	87.8-92.2	88.5-93.5	0.557[a]

[a] Mann-Whitney-U test, SD: standard deviation, CI: confidence interval

Table 4. Radiographic analysis of cup placement, offset reconstruction and leg length

approach	anterior	range	anterolateral	range	*p*-value
inclination (°)	38.2 (SD 4.2)	31-50	39.4 (SD 4.5)	31-51	0.07
anteversion (°)	15.8 (SD 3.4)	10-30	16.4 (SD 4.9)	5-30	1.00
offset (%)	99.5 (SD 6.6)	77.5-109.1	95.9 (SD 12.9)	59.6-155.1	0.02*
leg length (mm)	-0.4 (SD 3.0)	-5.5-9.5	1.28 (SD 4.4)	-9.9-12.9	0.001*

SD: standard deviation

Table 5. Peri- and postoperative complications.

complications	anterior	anterolateral
hematoma	0	1
early infection	1	5
dislocation	5	0
trochanteric fracture	1	1
Periprosthetic fracture	1	0
Leg length discrepancy >1cm	0	1

infection was observed (1.1%). The infection (Bacteroides fragilis) could not be managed successfully with debridement, irrigation, exchange of the mobile parts (DAIR) and intravenous antibiotic therapy resulting in two-stage exchange arthroplasty. There was a single minor superior greater trochanteric fracture (chip fracture), which occurred on day 5 after surgery and did not require fixation. It had no later clinical consequence. One patient was readmitted two weeks after surgery with a periprosthetic fracture (Vancouver B2) requiring surgical revision (open reduction, cerclage wires, replacement of stem). Five dislocations occurred in the series, three of which (anterior) were immediately reduced without any future consequence or recurrence. These three dislocations were, however, attributable to improper patient behavior due to postoperative delirium, the patients had undergone THA due to femoral neck fractures.

Another anterior recurrent dislocation was revised and treated with a hooded acetabular liner (Zimmer Durasul alpha hooded insert) in combination with an offset adapter (Merete BioBall system). Moreover, one recurrent posterior dislocation occurred due to an anterior bony impingement. During revision, a partial trochanteric reduction osteotomy was performed, the anterior acetabular rim was trimmed, and a hooded liner was chosen.

We observed a significantly higher rate of early deep infection (5.7%) with the anterolateral approach compared to the DAA (1.1%) (p=0.039). Four of these infections (3 Staphylococcus epidermidis, 1 Cutibacterium acnes) could be successfully managed with DAIR. One infection on the other hand (Staphylococcus epidermidis and Cutibacterium acnes) resulted in a two-stage revision surgery due to cup loosening.

Moreover, in the ALMI group one trochanteric chip fracture was seen. It was treated conservatively. Furthermore, one patient had to be subjected to revision surgery due to a considerable perioperative hematoma. Additionally, in three cases a leg length inequality (LLD) of more than 1 cm was documented, a rate significantly higher than in the DAA group. These LLDs were of clinical relevance. As a result, the affected patients received orthopaedic insoles.

With both approaches, all complications requiring revision surgery occurred within the first 60 cases.

DISCUSSION

Approaches for minimally invasive hip arthroplasty become increasingly popular[12] due to decreased rates of perioperative anaemia, reduced pain levels after surgery and quicker mobilization.[13–15] Moreover, the clinical outcome is equivalent compared to hip function after THA utilizing traditional approaches.[16,17] However, usage of these lesser invasive approaches is technically challenging as reflected in reported complication rates.[18–20] This has nurtured widespread discussions regarding learning curves.[21,22] Learning curves of surgical techniques can commonly be subdivided into four stages. An early rapid ascent, a period of decreasing improvement, a plateau phase and a time of slowly age-related decrease in outcome quality.[23]

In the present study, we analysed the outcome of 95 patients that received THA via the DAA in supine position. The results were compared to hip replacement in 88 patients utilizing the ALMI approach in lateral recumbency. The DAA and ALMI showed comparable functional outcomes and activity levels. Hip function assessed utilizing the HHS did not differ significantly. The documented outcome scores for both the DAA and ALMI group were within an expectable margin and in line with previous reports.[3,15] However, it has to be noted that the HHS has a limited discriminative ability due to a restricted amount of challenging items causing a ceiling effect.[24]

The time from incision to suture showed no significant difference comparing both groups. But it significantly decreased over the study course. Compared to previous reports the operative time was considerably shorter. It summed up to 72.5 minutes (SD 15.8) and 71.4 minutes (SD 15.4) with early cases and 55.0 minutes (SD 9.3) and 54.2 minutes (SD 8.6) at late stages.[25]

Component positioning and function gain increasing recognition as decisive factors determining THA stability and survival. With both approaches cup orientation in any case was within the safe zone proposed by Lewinnek.[26] Nonetheless, five dislocations occurred within the DAA group (5%). These dislocations occurred within the first 60 surgeries. They had an average cup inclination of 38.4 degrees (38-44°), an average anteversion of 16.2 degrees (14-20°), and a good restoration of leg length (average -0.6 mm; -2.5-0.5 mm) and offset (98%; 91.8-103.8%). This indicates that additional factors to component positioning play a pivotal role for stability such as the reestablishment of hip specific biomechanical conditions, protection and tension adaption of the surrounding soft tissue, head diameter, cup selection, and the method of surgical joint exposition.[27–30] Most likely, the rate of dislocation could have been positively influenced by choosing unconstrained tripolar cups when treating incompliant patients or displaced femoral neck fractures in aged inpatients.[31] Tripolar cups therefore have to be considered in the future for these cases.

Unequal leg length in adults is frequently associated with total hip arthroplasty. Equality of leg length is, however, desirable as slight discrepancies can result in afflictions including lower back sorrow, sacro-iliac joint and muscle dysfunction.[32,33] In general, with the DAA, femoroacetabular offset and leg length were reconstructed to a significantly higher degree when compared to the ALMI approach despite the routine use of fluoroscopy to control component placement intraoperatively. This is in line with previous reports.[34,35] One reason might be the lateral decubitus position and the associated patient/pelvic rotation.[36] This complicates the accurate acquisition of reliable intraoperative images for leg length and offset assessment. Other methods such as the evaluation of soft tissue tension or shuck tests as well as the palpation of clinical landmarks may be misleading due to the neuromuscular blockade affected by the mode of anesthesia and the adduction of the operated limb in a lateral position.[37]

We observed a significantly higher rate of periprosthetic joint infections (PJI) with the anterolateral approach. Consequently, our study results support the hypothesis of a significant association of PJI with the anterolateral approach.[38] A review of available literature nevertheless shows inconsistent results regarding the influence of the approach on PJI rates. A variety of reports do not confirm the increased number of revisions attributed to the anterolateral approach when compared to the posterior or lateral transgluteal approaches or the DAA.[39,40]

Moreover, with the DAA an incidence of 2.1% was documented for LCFN affections. Considerably higher incidences were published previously (16%).[41,42] The LCFN carries afferent sensory fibres and provides sensation to the anterior and lateral thigh. It commonly shows anatomic variants.[43] Consequently, the LCFN can easily be injured exposing the hip joint via the DAA. In all patients affected, LCFN associated hyp- or paraesthesia was of temporary nature.

Abductor deficiency in relation to THA can be observed in 0.08% and 22% of all patients.[44] A frequent cause is iatrogenic injury of the N. gluteus superior and dissolution of the gluteal muscles inserting at the trochanter major.[45,46] Notably, abductor weakness after THA is diagnosed more often in women.[47] Generally, abductor weakness is more likely to result when the surgical approach (anterolateral, lateral, posterior) used relies on a soft tissue release in proximity of the greater trochanter. The DAA on the other hand allows the preservation of the gluteus tendons/muscles.[48,49]

Gluteal insufficiency, however, did not occur more frequently using the ALMI. This is in line with previous reports.[47,50]

The presented study faces certain limitations. It is a monocentric study including the data of a single surgeon only. The higher drop-out rate in the anterolateral cohort might have led to an insufficient sample size. Moreover, the defined exclusion criteria related to comorbidities could have biased the outcome with both approaches.

CONCLUSION

We suggest that the supervision by an experienced surgeon favourably influences the learning curve of trainees newly introduced to both the minimally invasive DAA in supine and anterolateral approach in lateral recumbency and conclude that the greatest improvement is seen within the first 60 cases.

AUTHOR CONTRIBUTIONS

Conceptualization, J.R. and U.N.; methodology, J.R, G.W. and U.N.; validation, J.R., U.N. and E.R.; formal analysis, J.R. and E.R; investigation, J.R.; resources, U.N and G.W.; data curation, J.R.; writing—original draft preparation, J.R. and G.W.; writing—review and editing, G.W. and U.N; supervision, U.N. and G.W.; project administration, J.R. and E.R.; All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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INSTITUTIONAL REVIEW BOARD STATEMENT

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the institutional review board.

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study.

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