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ORIGINAL STUDY

Learning curve of direct anterior total hip arthroplasty : a single surgeon experience

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There is strong evidence that the minimal invasive direct anterior approach for primary total hip arthroplasty (DAA-THA) is responsible for a faster return to function and daily activity and an enhanced short-term recovery and rehabilitation in comparison with other total hip approaches. The effect of the learning curve on patient safety and surgical outcome after commencing with the direct anterior surgical approach remains unclear. This single surgeon study presents the postoperative results of the initial 200 cases after implementing the direct anterior approach (DAA) compared with the initial 200 cases after implementing a 24 hours time-based fast-track program using identical technique by the same surgeon. The effect of the learning curve has been described in operative parameters, overall complications and radiological component placement. The complication rate of the initial 100 cases after commencing with the direct anterior operation technique was high and declined thereafter. After implementing a new time-based fast-tack program with identical DAA-THA technique we found from the outset unchanged low complication and revision rates. The learning phase in performing the direct anterior hip replacement is rather long but the incidence of complications decreases with greater surgeon experience and does not increase after implementing a new time-based fast-track program. In this study the learning curve could be defined over 100 cases.

Keywords : learning curve ; direct anterior approach ; total hip arthroplasty ; focus clinic ; qualitative study.

INTRODUCTION

The presence of a learning curve after implementing a new operative technique is well documented. The effect of the learning curve for the direct DAA-THA has been reported before with varying results *(3,8,18,19,21,24,30)*. The parameters regarding the learning curve have been well described but the outcome concerning the learning phase differs considerably. The number of cases regarding the learning curve varied from as little as 10 to as many as 200 *(2,3,9,19,30)*. It has been reported that in comparison with other total hip approaches the DAA is associated with more complications, especially in the learning phase *(5,9,17,25)*. Few studies have documented a surgeon's individual learning curve when using the DAA for THA *(17,19,22,27)*. In this study we retrospectively compared two groups of 200 patients with primary THA for osteoarthritis (OA), osteonecrosis or developmental arthritic disease,

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regarding the learning curve and patient safety. All the patients were operated on by a single surgeon, who carried out uncemented DAA-THA. The first group consists of the initial selected 200 cases after commencing with the DAA technique in a large volume non-university hospital. The second group consists of the initial consecutive 200 cases operated on after implementing a new 24 hours patient-centered time-based fast-track program in a highly specialized hip unit. All procedures were performed by the same surgeon using identical technique. With this study we primary tried to evaluate the length of the learning curve and the effect on patient safety after implementing a new surgical approach for total hip replacement. Secondly we tried to investigate if the implementation of a new time-based fast-track recovery and rehabilitation program influences the outcome concerning the learning phase and patient safety.

MATERIALS AND METHODS

We retrospectively reviewed the data collected in a cohort of two groups of 200 patients with ASA classification I, II, and stable III who underwent a primary direct anterior THA performed by a single orthopaedic surgeon who started operating according to the DAA-THA technique in 2006. The initial group of 200 selected patients was operated on in the Medical Center of Alkmaar (MCA) in the Netherlands, a large volume non-university hospital, commencing November 23, 2006. The second group of 200 consecutive patients was treated with the same DAA in a specialized hip clinic with a dedicated staff and a uniform approach towards giving the patients the evidence-based care principles as from March 1, 2012. In both groups we documented the surgery time, blood loss, length of stay (LOS), operative and systemic complications, reoperations, readmissions and component placement within 90 days postoperatively. All procedures were performed by a single surgeon (FvdE) using the direct anterior Hueter approach with a positioning table (AMIS Mobile Leg positioner, Medacta) as described by Laude in 2006 without fluoroscopy *(15)*. All patients were followed up for at least 1 year post surgery. In the initial group of 200 patients (group I) identical uncemented implants were used. All acetabular components were uncemented porous-type press-fit Versafit cups, with ceramic on ceramic or ceramic on XLPE bearing surfaces and an uncemented Quadra stem with a 32-mm head (Medacta international SA, Strada Regina 6874 Castel San Pietro, Switzerland). In the second group of 200 patients (group II) the uncemented femoral and acetabular components consisted of a Trinity cup, a Metafix stem, a crosslinked polyethylene or polyethylene liner and a cobalt-chrome or ceramic 32-mm head (Corin Group Cirencester, UK). Preoperative templating had been performed for every patient. The patients from the first group, who benefited from a DAA, were not included in any kind of fast-track or rapid recovery protocol. The anaesthesist decided on a case by case basis whether a general or spinal anesthesia was appropriate. A preoperative pain protocol was not used. Rehabilitation started on the first postoperative day and all patients were allowed full weight bearing without specific precautions against dislocation. Discharge followed when the patients were able to walk with 1 or 2 crutches, to climb stairs, to go to the toilet, to get in and out of bed and to dress independently and who felt comfortable leaving the hospital. All patients were treated and followed by their general practitioner and physiotherapist at home. Thrombosis prophylaxis (Acenocoumarol) was given for 6 weeks postoperative. The first post-op consultations were scheduled for 6 weeks, 3 months and 1 year.

In the second group the preoperative and postoperative principles of a time-based fast-track treatment are followed in which an intended discharge time after 24 hours is set, taking into account that the functional discharge criteria, as mentioned above, have to be fulfilled apart from being able to put on one's own socks and shoes. All patients were extensively informed and educated about the day case program and signed an informed consent form. All patients were operated on under general anesthesia to accommodate muscle relaxation requirements. They benefited from an identical preoperative and postoperative time-based fast-track regimen including a multimodal

opioid sparing pain treatment regimen. This was combined with early full-weight bearing mobilization starting 3-4 hours postoperative and short deep-vein thrombosis prophylaxis with low-molecular-weight heparin (Fraxiparine 0,4-3.800 IE) starting 5-7 hours after surgery for a total of 10 days. Tranexamic acid (TXA) was infused as an intravenous bolus of 1,000 mg at induction and 500 mg was given intravenously 4 and 6 hours postoperatively. No restrictions in postoperative mobilization or aftercare were prescribed the only exception being hip flexion more than 120 degrees. Physiotherapy is prescribed in certain cases, after the first postoperative consultation.

For both groups radiographic analysis was based on the first postoperative standard AP pelvic and lateral views. We evaluated component positioning by measuring acetabular cup inclination, femoral stem alignment and leg length discrepancy (LLD). Cup inclination was measured using the angle of the cup in relation to the transischial line. An inclination between 35 and 55 degrees was considered adequate. Stem alignment was classified as varus or valgus position when the angulation was more than 3 degrees. LLD from 1 to 2 cm was registered for shortening or lengthening. Shortening of more then 2 cm was reported as femoral subsidence or extensive shortening, lengthening of more then 2 cm was evaluated as extensive lengthening of the operated leg.

Statistical analyses were carried out using the SPSS Statistics, version 20 (IBM Corporation, Armonk, NY, USA). Non-parametrical tests were used to compare different sub-groups in our series (Mann-Whitney U-test, Fisher exact test, Pearson Chi-square test and Kruskall-Wallis). A p-value < 0.05 was set as statistically significant.

RESULTS

400 patients took part in this study, 105 men and 295 women. They were divided in two groups of 200 patients, all operated on with an identical technique using a traction table without fluoroscopy. Group I and II were comparable when looking at age and ASA classification. In the first group all patients were selected concerning gender and BMI to perform the DAA-THA. In the second group all the consecutive patients were treated using the DAA technique without patient selection and all the patients were routinely operated under general anesthesia. The patient characteristics of the two groups are shown in Table I. In the first group we lost 27 patients for radiological evaluation and 3 patients in the second group. The primary outcome measures were the operative and radiological

Table I. — Patient characteristics of the 2 groups

	Group I			Group II		
	Mean	Range	SD	Mean	Range	SD
Age (years)	65,7	45-83	7,3	66,1	32-85	8,1
BMI	24,8	19-29	2,4	25,0	18-37	3,1
Gender : male	41			64		
: female	159			136		
ASA I	106			98		
II	92			98		
III	2			4		
Anaesthesia (%)						
Regional	58			0		
General	42			100		

BMI =body mass index, kg/m², ASA= American Society of Anesthesiologists, In group I : 23 incomplete patient characteristics concerning BMI : n = 177;

parameters and the complication rate at discharge and 90 days postoperatively.

To evaluate the learning curve, both groups were divided in 4 sub-groups of 50 patients depending on the sequence in time of operation, as shown in Table II. The OR-time, blood loss, LOS, complications, re-admissions and reoperations of both groups and sub-groups were compared.

The average surgery time and blood loss of the first group decreased from 115 minutes and 700 mL to 70 minutes and 400 mL after 200 cases. The LOS diminished from 5,6 days to 3,9 days in the same period (average 4,8 days; SD: 2,1; range 1-11). The average OR-time and blood loss of the second group were, initially 60 minutes and 340 mL and did not change over time. The LOS was approximately 1 day (average: 25,2 hours; SD: 1,2; range 22-29 hours).

3 femoral fractures, 2 acetabulum fractures, 3 cup loosening, 4 implant failures (ceramic cup breakage), 2 dislocations, 1 per-operative diagnosed femur perforation, 1 stem subsidence and 1 Tensor Fascia Lata muscle dissection were observed. We found 4 patients with a superficial infection, 3 patients with a deep venous thrombosis (DVT) and 1 patient died direct postoperatively caused by a massive acute myocardial infarction which was confirmed by autopsy.

In the second group, 1 trochanteric fracture, 1 calcar fissure, 1 femoral perforation, 1 subsidence and 2 dislocations were seen. 1 heavily smoking patient was diagnosed with a DVT and could be treated nonoperatively. We did not find further non-surgical complications as pulmonary embolism (PE), pneumonia, myocardial infarction, postoperative delerium or cerebrovascular accident.

Table II. — Patient characteristics and operative outcomes of the subgroups

Group I	Gr. I-A	Gr. I-B	Gr. I-C	Gr. I-D
N=200	*n=50*	*n=50*	*n=50*	*n=50*
Age years (range)	65,9(45-77)	65,7(49-82)	66,7(56-79)	64,6(54-83)
Gender (% men)	18%	20%	14%	22%
OR-time :min (range)	115 (75-135)	100 (65-135)	75 (55-120)	70 (45-105)
Blood loss (mL)	700 (400-1900)	620 (350-1200)	470 (150-800)	400 (150-500)
LOS (days)	5,6 (1-11)	4,7 (1-7)	4,8 (1-8)	4,2 (1-7)
Group II	Gr. II-A	Gr. II-B	Gr. II-C	Gr. II-D
N=200	*n=50*	*n=50*	*n=50*	*n=50*
Age years (range)	64,9(46-76)	65,2(40-79)	65,8(32-81)	66,1(40-85)
Gender (% men)	32%	26%	30%	40%
OR-time :min (range)	63 (45-105)	63 (45-135)	62 (40-85)	62 (35-85)
Blood loss (mL)	335 (150-700)	340 (150-850)	325 (150-700)	340 (100-1200)
LOS (hours)	25,6 (23- 28)	25,7 (23-28)	25,6 (23-28)	25,5 (22-28)

SubGroup n= 100: Gr.I-A + Gr.I-B : OR-time 107,5 min, Bld loss: 660 mL
SubGroup n= 100: Gr.I-C + Gr.I-D : OR-time 72,5 min, Bld loss: 435 mL
p-value<0.001

The total number of complications, reoperations and re-admissions within 90 days postoperatively concerning the initial 200 cases were respectively 40, 18 and 23 decreasing clearly over time. The total number of complications, re-operations and re-admissions concerning the second group within the same period postoperatively were respectively 17, 4 and 5.

In the first group a total number of 40 complications were seen of which 23 operative complications.

The different subgroups of the first group did not show a statistically significant difference concerning the OR-time and blood loss except between subgroup IB and IC with a p-value of <0.01. If the subgroups IA and IB were added and compared with the total of the sum of subgroup IC and ID, there was a statistically significant difference concerning the operating time and blood loss with a p-value <0.001. All complications

reoperations and re-admissions for both groups are detailed in Table III.

Radiographic analysis of the radiographs taken at 2 or 6 weeks after surgery showed a median acetabular cup inclination angle of 47.4 degrees. within the safe range of 35-55 degrees with a cup position that varied between 20-60 degrees (Mean = 46.8, SD: 3.6) (p-value<0.01). The most of the outliers of the first group were found in the initial 100 cases and showed some steep positions. 10 out

Table III. — Complications, re-admissions and reoperations of the subgroups within 90 days postoperatively

Operative complications	**I A**	**I B**	**I C**	**I D**	**II A**	**II B**	**IIC**	**II D**
Femur fracture	1	1		1				
Acetabulum fracture	1		1					
Femur perforation	1				1			
Calcar fissure					1			
Greater trochanter fracture				1				
Cup loosening		1		2				
Implant failure			1	3				
Dislocation	1		1			1		1
Stem subsidence	1						1	
TFL rupture			1					
Non operative complications								
LFCN injury (temporary)	2	3	1	1		1	2	1
Wound infection								
-superficial	1	2		1	1		1	
-deep					1			
Wound hematoma	2	1	2	1	1	2	1	
DVT		2		1				1
MI		1						
Death		1						
Total for the sub-groups	15	12	8	5	5	4	6	2

Total Group I : Complications: 40 Reoperations: 18 Re-admissions: 23
SubGroup n= 100 I-A+I-B : Complications: 27% Reoperations: 12% Re-admissions: 16%
SubGroup n= 100 I-C+I-D : Complications: 13% Reoperations: 6% Re-admissions: 7%
p-value<0.001
Total Group II : Complications: 17 Reoperations: 4 Re-admissions: 5
N=200 : Complications: 8,5% Reoperations: 2% Re-admissions: 2,5%

The radiological outcome is shown in Table IV. The cup inclination of both groups is recorded in figure 1. In Group I the retrospective collected data was not complete. 27 patients were lost to radiological follow-up leaving 173 patients for evaluation. From the first 100 cases 15 patients were lost to radiological follow-up. 12 patients of the following 100 operations lacked radiological follow-up. 146 out of 173 cups (84,4%) were positioned between the range of 35-55 degrees with a variation of 28-64 degrees (Mean = 48.3, SD: 3.8). In Group II 3 patients were lost to follow-up leaving 197 for evaluation. 172 out of 197 (87,3%) were placed of 17 outliers with steep cup placement of 55-59 degrees and 5 out of 7 outliers of more than 60 degrees were situated in the first 100 operations (N=85). In the following 100 cases the outlying steep cup positions were reduced to 5 of 55-59 degrees and 2 of more than 60 degrees (N=88). 19 patients in the second group, showed outlying flat cup positions in the range less than 35 degrees as seen in figure 2.

The alignment was radiological investigated in AP and lateral views. A number of femoral components in Group I showed a minor varus position of more than 3 degrees. 34 out of 173

Table IV. — Radiological outcome

Radiological outcome	group I (N=173) Mean (SD)	Min-Max	group II (N=197) Mean (SD)	Min-Max	*p*-value
Inclination (degrees)	48,3 (3.8) .	28-64	46,8 (3,6)	20-60	<0.01
Stem position	Minor varus	N=34	Minor varus	N=2	<0.01
	Neutral	N=136	Neutral	N=195	
	Minor valgus	N=3	Minor valgus	N=0	
Leg Length discrepancy	Ext. L >2cm	N=0	>2cm	N=2	
	Mod. L +1cm	N=22	+1cm	N=14	
	None	N=148	None	N=180	
	Mod. S -1cm	N=2	-1cm	N=0	
	Ext. S -2cm	N=1	-2cm	N=1	

SD = standard deviation

in Group I (20 %) and 2 out of 197 in group II (1%). Valgus position of the stem did only occur in 3 cases in group I and was not found in group II. One shortening of more than 3 cm in the first group and one traumatological subsidence of the femoral component with shortening of more than 2 cm in the second group did occur and needed revision both times to correct leg length and to guarantee stability. Leg length discrepancy (LLD) was clinically relevant in a very small number of cases. In the first group a moderate lengthening of more than 1 cm occurred in 22 of the 173 cases (13 %) without clinical effect. In the second group a total of 16 of the 197 (8 %) cases showed moderate lengthening of more than 1 cm. 2 patients of the second group showed an extensive lenghtening of more than 2 cm and required a non-operative orthopedic shoe-adjustment.

DISCUSSION

The presence of a learning curve after implementing a new operative technique is well documented. Many factors may affect the learning curve for total hip arthroplasty (THA) and the surgical approach is one of these *(27)*. Although the effect of the learning curve for the DAA has been reported before it is still not yet clear *(11)*. Few studies have documented a surgeon's individual learning curve when using the DAA for THA *(7,17,19,22,27)*. In this single surgeon study we investigated the learning curve of the DAA-THA using a positioning table without fluoroscopy with regard to operative parameters and immediate outcomes. Secondly we studied the learning curve after implementing a new time-based fast-track program using the same operation technique.

We started this approach by reason of strong evidence that the direct anterior approach is responsible for faster return to function and daily activity and an enhanced short-term recovery and rehabilitation in comparison to other approaches of the hip joint *(11,22,23,24,31)*.

The question has been posed: is there a minimum number of cases required to complete a learning curve for this procedure? *(27)* As in other studies we investigated the OR-time, blood loss, LOS, complications, re-admissions, reoperations and implant placement as parameters concerning the learning curve as shown in Table V.

The operating time and blood loss decreased from a mean time of 115 minutes and 700 mL at the beginning of this study to 100 minutes and 620 mL after 100 cases. After 200 cases the OR-time and blood loss decreased further to 70 minutes and 400 mL. Masonis et al. demonstrated similar

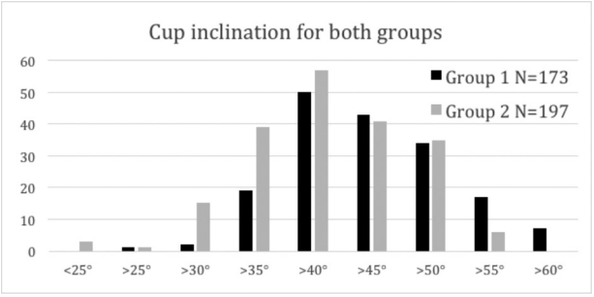

Fig. 1. – Cup inclination for both groups in degrees

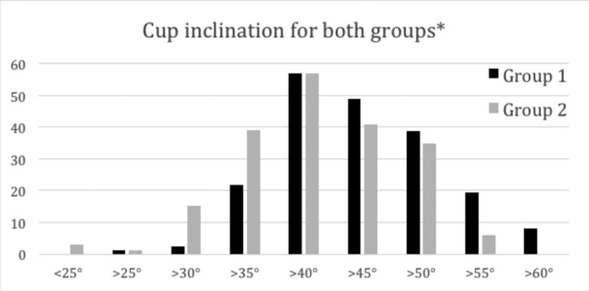

Fig. 2. – Cup inclination for both groups in degrees

significant reductions in operation time after the initial 100 cases. In his study mean surgery time was 133 minutes for the first 100 cases and 110 minutes for the second 100 cases and 106 minutes after having done more than 200 *(17)*. Goytia et al. studied 4 groups of 20 patients regarding operative time and blood loss. In his study, the operative time decreased from 124 to 98 minutes and the estimated blood loss decreases from 596 to 347 mL. after 60 cases *(8)*. In all the other studies investigating surgery time the same reduction of approximately 30 minutes OR-time have been documented each with different number of cases required to complete the learning curve for this procedure *(2,4, 9,18,22, 24,31)*.

In comparison with other studies concerning the postoperative complications we found that our first outcomes were comparable with other publications implementing this procedure and showed quite a number of complications *(1,5,16)*. Looking at the total complication rate, re-admission and reoperating rate the same evolution over time was adjusted. In our study the initial 100 cases of group I showed an operative complication rate of 12% (12/100) against 6% (6/100) for the next 100 cases ($p<0.001$). The overall complication rate for the initial 100 cases numbered 27 against 13 for the next 100 cases ($p<0.001$). The same observation was made concerning the re-admission and reoperation rate. The overall re-admission and reoperation rate were 16 and 12 for the initial 100 cases and 7 and 6 for the for the subsequent 100 cases ($p<0.001$). Specific complications for DAA such as trochanteric fractures, femoral perforations, femoral fractures and acetabular fractures occurred. We saw 2 femoral fractures, 1 acetabular fracture and 1 femoral perforation in the initial 100 cases of our study. In the second 100 cases we determined 1 femoral and 1 acetabular fracture. These findings were in accordance with the specific problems from the DAA-THA described in other studies *(14,16)*.

The overall complications mentioned by Alexandrov et al. in a series of 35 consecutive DAA-THA showed 1 femur fracture, 3 greater trochanteric fracture, 1 postoperative periprosthetic intertrochanteric fracture, 2 femoral nerve palsy and 1 postoperative iliopsoas avulsion *(2)*. In 2013 Yi et al. reported a high incidence of complications during the early learning curve of the DAA-THA using a traction table. In their study an overall complication rate of 16.4% (10/61) with 4 (6.5%) reoperations did occur as a result of the learning curve *(29)*. De Steiger et al. reported a cumulative percent revision of 3% for surgeons performing 51 to 100 operations and a revision rate of 2% for surgeons doing more then 100 operations *(27)*. Horne and Olson concluded in 2011 that the fracture rate is inversely related to the experience of the surgeon and that a volume up to 200 cases is needed to reduce the complication rate as an effect of the learning curve *(12)*. As a conclusion Wayne et al. stated in 2009 that the substantial increase in overall complications associated with the anterior approach, may give doubts as to the safety of this procedure *(28)*.

The variation concerning the length of the learning curve in literature is extraordinary and controversial. The number of cases regarding the learning curve varies from as little as 10 to as many as 200 (Table V). Some studies reported a learning phase of 10 to 30 cases. *(2,4,19,21)*. Other studies describe the tissue sparing minimal invasive DAA-THA technique as a demanding procedure with a long learning curve up to 100-200 cases *(1,9,17,22,27)*. In some studies a high rate of complications have been described based on lack of visualisation of the surgical field *(4,25,28,29)*. Wayne et al. reported in 2009 no ending of the learning phase regarding OR-time after 100 cases *(28)*. Others did study very small numbers and did not see any difference in operative blood loss *(4,25)*. In another multicenter study with 5499 THAs, a reduction of revisions was not to be expected until

surgeons had performed over 50 operations *(27)*. In another cohort study of 1,152 patients treated with the anterior approach to total hip arthroplasty, the authors found a reduction of complications in surgeons doing more then 100 cases. Surgeons who performed less than 100 cases were likely to have two times more complications *(3)*. In our study we observed the most dramatic drop in OR-time, blood loss and overall complication rate after the initial 100 cases. These parameters decreased slightly resulting in decreased variability of acetabular cup placement *(21)*. Radiographic analysis by Matta et al. showed an average abduction angle of 42 degrees, with 96% in the range of 35 degrees to 55 degrees abduction with the use of fluoroscopy. These findings support that the outcome of acetabular component positioning is accurate and reproducible with fluoroscopy *(16)*. De Geest et al. stated an accurate placement of the cup without fluoroscopy in 91,6% out of 300 patients with the

Table V.— Length of learning curve concerning the DAA-THA in the literature

Author	N	Mean age	Gender (%male)	BMI (kg/m²)	Study Parameters	
Learning curve						
Alecci et al 2011(1)	221	71	45	NM	OR, C	200
Alexandrov et al 2014(2)	43	62	33	26	C, RX	30
Bhandari et al 2009(3)	1152	65	48	28	C	100
D'Arrigo et al 2009(4)	20	64	60	23	OR	10
De Geest et al 2013(5)	300	70	45	NM	RX	>100
Goytia et al 2012(8)	81	58	52	28	OR, C, RX	60
Hallert et al 2012(9)	200	67	40	27	OR, C, RX	200
Masonis et al 2008(17)	300	59	36	29	OR, C, RX	100
Melman et al 2015(18)	182	69	25	28	OR, C	120
Muller et al 2014(19)	150	64	48	27	C, RX	20
Pogliacomi et al 2012(21)	30	68	50	27	OR, C, RX	30
Rathod et al 2014(22)	286	62	46	26	RX	100
Seng et al 2009(24)	182	NM	NM	NM	OR	40
Spaans et al 2012(25)	46	69	52	25	OR, C, RX	> 23
de Steiger et al 2015(26)	400	NM	NM	NM	C	100
Wayne et al 2009(27)	100	6	29	27	OR, C, RX	100
Woolson et al 2009(28)	247	68	39	NM	OR, C	50
Yi et al 2013(29)	61	56	54	28	C, RX	30
Zawadsky et al 2014(30)	100	60	48	30	C50	

OR: operative parameters, C: complcations, RX: radiological component placement - NM = not mentioned

after performing over 200 cases as documented in other studies *(16,20)*.

Improvement of implant placement with the DAA technique was also reported with growing experience. Masonis and Rathod showed an improvement of the radiological outcome regarding the acetabular cup inclination, stem alignment and LLD after 100 cases *(17,22)*. In our study most of the outliers regarding the cup abduction and LLD were situated within the initial 100 cases and decreased in the following 100 cases to remain practically the same thereafter. There seems to be no difference, in our study, between the clinical and radiological findings regarding the learning curve and could be situated around 100 cases. In the study from De Geest et al. in 2013 similar results were reported. Most of their outliers were also found in the initial 100 patients of the series *(5)*. The results of other studies were in accordance with these findings *(9,27)*. But in contrast with these findings of 100 cases concerning the learning phase regarding radiological outcome, a short curve of 30 has been reported by others *(2,21,30)*. A clear definition of the learning curve regarding radiographic outcome is difficult but tends to be more then 50 cases.

Some studies reported the use of fluoroscopy to improve the implant placement and diminish LLD. Rathod et al. reported that the use of fluoroscopy with the patient in the supine position enables intraoperative assessment of cup orientation

outliers within the initial 100 cases *(5)*. In our study without fluoroscopy we reached a good component placement outcome in 84,4% in Group I (N= 173). 82,1 % of the initial 85 cases showed an accurate component placement and 86,7% of the following 88 cases. In Group II (N=197) a good component placement was reached in 87,3%. According to Rathod et al. there is strong evidence that there is no difference in postoperative component placement between the anterior approach and the other studied approaches *(22)*. But it still remains unclear if the use of intraoperative fluoroscopy with the DAA-THA decreases acetabular cup variability and LLD in the learning phase.

In the second part of our study we investigated if the implementation of a new fast-track protocol could influence the learning curve. The outcome of investigations made in other studies for fast-track total hip and total knee arthroplasties (TKA) did show that fast-track for THA and TKA is completely safe with higher patient satisfaction. *(10,31)*. In our study of the initial 200 unselected cases (Group II) after implementing a new time-based fast-track the complication rate did not increase and the fast-track program resulted in shorter LOS with a higher patient satisfaction without compromising patient safety as mentioned in other studies *(5,6,10,13)*. After implementing a new time-based fast-track program with a LOS of 24 hours while maintaining the well-known operative technique, a learning curve is nonexistent despite the change of the prosthesis. The implementation of a new fast-track THA protocol can be excluded as a factor that could affect the learning curve.

Some potential limitations of our study need to be discussed. The weakness of this study is its retrospective design with a short 1-year follow-up and uncomplete data. The purpose of this study was to examine the learning curve for the DAA-THA concerning operative parameters and short term patient safety. The review was completed on a single surgeon's initial series of 200 THAs performed using the DAA. Gofton reported that learning curve reports from single surgeon series have several limitations resulting from the limited dataset reported. Despite substantial limitations, single-surgeon series remain the most effective way for practising surgeons to assess their learning challenge and develop an appropriate learning plan. The interpretation of the results of a single surgeon learning curve study remain unclear and need further investigation to what extent their results can be generalized *(7)*.

We conclude that the learning period of the DAA-THA is inordinately long. Based on the results of our study we believe the learning curve has to be situated over 100 cases. In a high volume DAA-THA unit it potentially could be shorter if education and training play a major role *(24)*. The direct anterior operation technique for total hip replacement is demanding which can lead to specific starter problems and complications. As with all techniques, the skill and experience of the surgeon is critical to the success of the procedure *(12)*. During early cases, there will be a clear decline in quality of the arthroplasty in comparison with the approach that was previously being performed. As such, individual surgeons with a broader bell curve of execution may be less successful with DAA-THA *(23)*. Extensive education and training in learning this technique is strongly advised and is accompanied by major investment of time and energy with the inevitable "price" of a learning curve.

REFERENCES

1. **Alecci V, Valente M, Crucil M, Minerva M, Pellegrino CM, Sabbadini DD.** Comparison of primary total hip replacements performed with a direct anterior approach versus the standard lateral approach: perioperative findings. *J Orthop Traumatol*. 2011 ; 12 : 123-9.
2. **Alexandrov T, Ahlmann ER, Menedez LR.** Early clinical and radiographic results of minimally invasive anterior approach hip arthroplasty. *Adv Orthop*. 2014 ;2014: 954208.
3. **Bhandari M, Matta JM, Dodgin D, Clark C, Kregor P, Bradley G, Little L.** Anterior Total Hip Arthroplasty Collaborative Investigators, Outcomes following the single-incision anterior approach to total hip arthroplasty: a multicenter observational study. *Orthop Clin North Am*. 2009 ; 40 : 329-42.
4. **D'Arrigo C, Speranza A, Monaco E, Carcangiu A, Ferett A.** Learning curve in tissue sparing total hip replacement: comparison between different approaches. *J Orthop Traumatol* 2009 ; 10 : 47-54.
5. **De Geest T, Vansintjan P, De Loore G.** Direct anterior total hip arthroplasty: complications and early outcome in a series of 300 cases. *Acta Orthop Belg*, 2013 ; 79 : 166-73.

6. **Eeden van den YNT, De Turck BJG, Eeden van den FMC.** 24 hours stay after hip replacement. Implementation of a patient-centered time-based fast-track program. *Acta Orthop*, 2016 ; 88 : 24-28.
7. **Gofton WT, Solomon M, Gofton T, Pagé A, Kim PR, Netting C, Bhand ari M, Beaulé PE.** What Do Reported Learning Curves Mean for Orthopaedic Surgeons? *Instr Course Lect*. 2016 ; 65 : 633-44.
8. **Goytia RN, Jones LC, Hungerford MW.** Learning curve for the anterior approach total hip arthroplasty. *J Surg Orthop Adv*. 2012 ; 21 : 78-83.
9. **Hallert O, Li Y, Brismar H, Lindgren U.** The direct anterior approach: initial experience of a minimally invasive technique for total hip arthroplasty. *J Orthop Surg Res*. 2012 ; 25 ; 7 : 17.
10. **Hartog den YM, Mathijssen NM, Vehmeijer SB.** Reduced length of hospital stay after the introduction of a rapid recovery protocol for primary THA procedures. *Acta Orthop*. 2013 ; 84 : p. 444-7.
11. **Hartog den YM, Mathijssen NM, Vehmeijer SB.** The less invasive anterior approach for total hip arthroplasty: a comparison to other approaches and an evaluation of the learning curve - a systematic review. *Hip Int*. 2016 ; 26 : 105-120
12. **Horne PH, Olson SA.** Direct anterior approach for total hip arthroplasty using the fracture table. *CurrRev Musculoskelet Med*. 2011 ; 4 : 139-45.
13. **Husted H, Jensen CM, Solgaard S, Kehlet H.** Reduced length of stay following hip and knee arthroplasty in Denmark 2000-2009: from research to implementation. *Arch Orthop Trauma Surg* ; 2012 ; 132 : 101-4.
14. **Jewett BA, Collis DK.** High complication rate with anterior total hip arthroplasties on a fracture table. *Clin Orthop Relat Res* ; 2011; 469 : 503-7.
15. **Laude F.** Total hip arthroplasty through an anterior Hueter minimally invasive approach. *Interact Surg* ; 2006 ; 1 ; 5-11.
16. **Matta JM, Shahrdar C, Ferguson T.** Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. *Clin Orthop Relat Res*. 200 5; 441 : 115-24.
17. **Masonis J, Thompson C, Odum S.** Safe and accurate: learning the direct anterior total hip arthroplasty. **Orthopedics** ; 2008 Dec ; 31.
18. **Melman WP, Mollen BP, Kollen BJ, Verheyen CC.** First experiences with the direct anterior approach in lateral decubitus position: learning curve and 1 year complication rate. *Hip Int* 2015 ; 25 : 251-7.
19. **Muller DA, Zingg PO, Dora C.** Anterior minimally invasive approach for total hip replacement: five-year survivorship and learning curve. *Hip Int*. 2014 May-Jun ; 24(3) : 277-83.
20. **Oinuma K, Eingartner C, Saito Y, Shiratsuchi H.** Total hip arthroplasty by a minimally invasive, direct anterior approach. *Oper Orthop Traumatol*. 2007 ; 19 : 310-26.
21. **Pogliacomi F, Paraskevopoulos A, Costantino C, Marenghi P, Ceccarelli F.** Influence of surgical experience in the learning curve of a new approach in hip replacement: anterior mini-invasive vs. standard lateral. *Hip Int*. 2012 ; 22 : 555-61.
22. **Rathod PA, Bhalla S, Deshmukh AJ, Rodriguez JA.** Does fluoroscopy with anterior hip arthroplasty decrease acetabular cup variability compared with a nonguided posterior approach? *Clin Orthop Relat Res*. 2014 Jun ; 472 : 1877-85.
23. **Rodriguez JA, Cooper HJ, Robinson J.** Direct anterior approach to THR: what it is and what it is not. *Cutt Rev Musculoskelet Med*. 2013 ; 6 : 276-278.
24. **Seng BE, Berend KR, Ajluni AF, Lombardi AV Jr.** Anterior-supine minimally invasive total hip arthroplasty: defining the learning curve. *Orthop Clin North Am*. 2009 ; 40 : 343-50.
25. **Spaans AJ, van den Hout JAAM, Bolder SBT.** High complication rate in the early experience of minimally invasive total hip arthroplasty by the direct anterior approach. *Acta Orthopaedica* 2012 ; 83 : 342-346.
26. **Specht K, Kjaersgaard-Andersen P, Kehlet H, Wedderkopp N, Pedersen BD.** High patient satisfaction in 445 patients who underwent fast-track hip or knee replacement. *Acta Orthopaedica*. Vol. 86 ; No. 6 ; 2015 ; 702-7.
27. **de Steiger RN, Lorimer M, Solomon M.** What is the learning curve for the anterior approach for total hip arthroplasty? *Clin Orthop Relat Res*. 2015 ; 473 : 3860-6.
28. **Wayne N, Stoewe R.** Primary total hip arthroplasty: a comparison of the lateral Hardinge approach to an anterior mini-invasive approach. *Orthop Rev* (Pavia). 2009 ; 1.
29. **Woolson ST, Pouliot MA, Huddleston JI.** Primary total hip arthroplasty using an anterior approach and a fracture table: short-term results from a community hospital. *J Arthroplasty* 2009 ; 24 : 999-1005.
30. **Yi C, Agudelo JF, Dayton MR, Morgan SJ.** Early complications of anterior supine intermuscular total hip arthroplasty. *Orthopedics*. 2013 ; 36 : 276-8
31. **Zawadsky MW, Paulus MC, Murray PJ, Johansen MA.** Early outcome comparison between the direct anterior approach and the mini-incision posterior approach for primary total hip arthroplasty: 150 consecutive cases. *J Arthroplasty*. 2014 ; 29 : 1256-60.