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ORIGINAL PAPER

Incidence of heterotopic ossification in direct anterior vs posterior approach to total hip arthroplasty: a retrospective radiographic review

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Abstract
Purpose To investigate the prevalence of heterotopic ossification following direct anterior approach total hip arthroplasty compared to posterior approach, performed by a single surgeon at one institution
Methods All primary THAs performed by the senior author (JEL) over a 70-month period were reviewed, including 235 DAA and 120 posterior THAs. Brooker's system was used to grade HO at a minimum of six months follow-up.
Results Patients undergoing DAA were less likely to develop clinically significant HO compared to posterior THA (p= 0.04). The overall incidence of HO following DAA THA was 24.3 % (3 % grade 3 and 0 % grade 4), and following posterior THA was 27.5 % (4.2 % grade 3 and 3.3 % grade 4).
Conclusions Lower rates of clinically significant (Brooker grade 3 and 4) HO were observed in DAA THA than in posterior approach THA. This data may be instructive when approaching THA candidates with conditions that predispose them to HO.

Keywords Heterotopic ossification · Direct anterior approach total hip · Posterior approach total hip · Total hip arthroplasty · Brooker classification

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Introduction

Heterotopic ossification (HO) is a common complication following total hip arthroplasty (THA) that can lead to hip pain and decreased range of motion. The incidence of HO following THA varies widely in the literature, up to about 61 % [1, 2]. While the precise pathogenesis of HO is not fully understood, it has been proposed that trauma to soft tissues is an inciting event [3]. There are several risk factors for the development of HO that predispose certain populations to this complication. Some of these risk factors include hypertrophic osteoarthritis [4], ankylosing spondylitis [5], and diffuse idiopathic skeletal hyperostosis [6]. Varying degrees of HO following THA can develop, and the Brooker classification system [7] is the most commonly used classification scheme for grading the severity of HO on AP pelvis radiographs. This ranges from small bone islands (grade 1) to complete ankylosis of the hip joint (grade 4). Brooker grades 3 and 4 are considered clinically significant forms, ultimately leading to reduced clinical outcomes and decreased range of motion [21].

To date, there has not been a study comparing the incidence of HO following direct anterior approach (DAA) versus posterior approach THA performed by a single surgeon. A potential advantage of the DAA is that it permits less soft-tissue trauma during surgery compared to the posterior approach [9]. Only one study to our knowledge has examined the incidence of HO following DAA THAs, and reported an overall incidence of 41.5 %, which is consistent with the overall incidence of HO following THAs [10]. The purpose of the current study was to determine the incidence of HO following DAA versus posterior approach performed by a single surgeon at one institution. It was hypothesized that THAs performed using the DAA would have a lower incidence of clinically significant HO due to decreased soft-tissue damage.

Materials and methods

This study was approved by our institutional review board. All primary THAs performed by the senior author (JEL) over a 70-month period were reviewed. The following patients were excluded: those receiving dedicated HO prophylaxis (radiation, indomethacin), prior to hip surgery, age younger than 18 years, revision surgery, THA following hip fracture, one patient who underwent bullet removal from hip during THA, and those patients with less than six months of follow-up, resulting in exclusion of 55 patients. This left 377 anterior or posterior THAs to be included. There were 235 DAA THAs, and 120 posterior THAs. The following data was collected for each patient included in the study: surgical approach, sex, age at time of operation, race, BMI, comorbidities, pre-operative diagnosis, type of osteoarthritis (atrophic vs normotrophic vs hypertrophic), ASA classification, blood loss, operative time, number of blood transfusions required, length of hospital stay, and DVT prophylaxis received. One hundred and seventy-one patients were female, and 146 were male. The mean age of patients was 61.7 years, and the average BMI was 30.4. The demographics and comorbidities of patients are included in Table 1. The mean blood loss volume was 341 ml. Mean time of follow-up for all patients was 2.04 years (range 0.5–11.6 years). Pre-operative radiographs were examined for the presence of HO and the type of arthritis. The type of arthritis was classified based on Bombelli's system [11]. The description of operative parameters including anesthesia type, ASA status, operative duration, and blood loss were retrieved from patient medical records (Table 2). Postoperatively, HO was graded based on the standard Brooker classification system using standard AP pelvis radiographs (Figs. 1 and 2).

Description of direct anterior approach

For those patients undergoing the direct anterior approach, a modified Smith–Peterson approach was used. Patients were positioned supine positioning on a commercially-available specialized table with securable foot holders that allow intra-operative limb manipulation and traction. The superficial internervous plane between sartorius and tensor fascia lata is utilized, and the deep interval between rectus femoris and gluteus medius is developed to allow exposure to the hip capsule. Following capsulotomy, standard neck cuts and prosthesis positioning were used, with the aid of intra-operative fluoroscopy.

Description of posterior approach

For patients undergoing standard posterior approach, lateral positioning with a peg-board was used. Standard posterior approach via a trans-gluteal maximus split was utilized. External rotator detachment was completed, followed by standard capsulotomy, neck cut, and prosthesis positioning and implantation.

Statistical analysis methods

Descriptive statistics, including means and standard deviations for continuous measures and frequencies and proportions for categorical variables, were generated for all study variables. To assess differences in observed rates of HO and clinically significant HO, independent study measures were analyzed using PROC GENMOD version 9.3 (SAS, Cary, NC, USA), using logistic regression that accounts for the correlation within subjects who have more than one procedure as well as the correlation across subjects. Estimates for odds ratios and corresponding 95 % confidence intervals were generated.

Results

The overall incidence of HO in the DAA cohort was 24.3 %, while the overall incidence of HO in the posterior approach cohort was 27.5 % (Table 2). This translated to clinically significant HO in the DAA to be 3.0 %, and in the posterior approach group to be 7.5 %. The description of HO rates by Brooker type compared between the surgical approaches is included in Table 2.

A number of factors failed to demonstrate significant correlation with the development of clinically significant HO. Patient gender, age, BMI, race, operative time, blood loss, and the use of enoxaparin or fondaparinux all were not associated with development of clinically relevant HO.

Some variables demonstrated significant correlation with the overall incidence of HO, without stratification by grade. Males were more likely to develop HO after THA [p-value 0.0012, OR of 2.4 (1.4, 3.8)]. Increasing age was associated with higher rates of HO; increased age (OR in 5-year increments) demonstrated greater overall incidence [p-value 0.031, OR = 1.13 (1.01, 1.26)]. Additionally the use of aspirin for VTE prophylaxis was associated with non-significant decreased overall rates of HO (p-value 0.051)

There were multiple factors associated with differences in the rate of development of *clinically significant* (grade 3 or 4) HO (Table 3). Of primary interest was the surgical approach and VTE prophylaxis type. Those patients undergoing DAA were less likely to develop HO [p-value 0.041, OR = 0.36 (0.13, 0.96)]. Patients receiving aspirin as DVT prophylaxis were also less likely to develop HO (0.0064, OR = 4.0 (1.5, 10.6)). Two factors were associated with increased rates of HO. Patients receiving warfarin [p-value 0.014, OR = 4 (1.32, 12.5)], and patients receiving clopidogrel [p-value 0.009, OR = 7.1 (1.6, 33.3)] were statistically more likely to develop clinically significant HO. These data are recorded in

Table 1 Cohort demographics and comorbidities

	Anterior approach ($n = 235$)	Posterior approach ($n = 120$)	Statistical significance
Mean age (SD)	62.8 ± 12.3 years	58.5 ± 11.9 years	$p = 0.002$
Female	54.0 %	57.1 %	ns
Body mass index (BMI)	28.6 ± 5.1 kg/m^2	34.2 ± 9.2 kg/m^2	$p < 0.0001$
Race			
White	91.9 %	78.3 %	$p = 0.0006$
Black	1.7 %	7.5 %	$p = 0.013$
Hispanic	1.3 %	2.5 %	ns
Other/not reported	5.1 %	11.7 %	$p = 0.03$
Comorbidities			
Ankylosing spondylitis	0 %	0.8 %	ns
Anemia/blood dusease	3.4 %	0.8 %	ns
Asthma	8.5 %	5.8 %	ns
Back pain	23.0 %	29.2 %	ns
Cancer	16.6 %	14.2 %	ns
Depression	0.4 %	5.8 %	$p = 0.003$
Diabetes	6.0 %	15.8 %	$p = 0.003$
DISH	0 %	0 %	ns
GERD	29.4 %	30.0 %	ns
Head injury	0.4 %	1.7 %	ns
Heart disease	15.7 %	15.0 %	ns
Hypertension	49.4 %	62.5 %	$p = 0.02$
Hyperlipidemia	16.6 %	20.0 %	ns
Hypothyroidism	9.4 %	8.3 %	ns
Kidney disease	4.7 %	2.5 %	ns
Liver disease	2.1 %	1.7 %	ns
Lung disease	2.6 %	5.8 %	ns
Osteomalacia	0 %	0 %	ns
Osteoporosis	0.4 %	0.8 %	ns
Paget's dsease	0 %	0 %	ns
Parkinson's dsease	0 %	0 %	ns
Rheumatoid arthritis	0.9 %	0.8 %	ns
Obstructive sleep apnea	6.8 %	13.3 %	ns
Spinal cord injury	0 %	0 %	ns
Stomach ulcers	0 %	0.8 %	ns

Table 3, listed as odds ratios with associated confidence intervals.

Discussion

The purpose of this review was to compare the incidence of HO in DAA and posterior approach THA performed by a single surgeon at one institution. Our results show that patients who underwent DAA were significantly less likely to develop clinically significant (Brooker grade 3 or grade 4) HO when compared to patients who underwent posterior approach to THA. This effect may be explained by the anterior approach, relying more on intermuscular planes for dissection, which ultimately incites less local trauma.

The DAA has recently gained popularity in arthroplasty surgery due to the possibility of decreased soft-tissue trauma and post-operative patient functional advantages [20, 9]. Bergin et al. [9] examined serum markers of muscle damage by measuring post-operative serum creatine kinase (CK) levels following DAA and posterior THAs, and found lower levels of CK in DAA THAs compared to posterior THAs, supporting the concept of lower degree of soft-tissue damage in DAA THAs. The pathogenesis of HO following THAs is not fully understood, but soft-tissue trauma is likely an inciting factor, secondary to release of

Table 2 Cohort operative and outcome comparison

		Anterior approach ($n = 235$)	Posterior approach ($n = 120$)	Statistical significance
Heterotopic ossification	Grade 1	14.5 %	5.8 %	
	Grade 2	6.8 %	14.2 %	
	Grade 3	3.0 %	4.2 %	
	Grade 4	0 %	3.3 %	
ASA status	1	4.4 %	3.4 %	ns
	2	55.9 %	43.2 %	$p = 0.03$
	3	39.3 %	52.5 %	$p = 0.02$
	4	0.4 %	0.8 %	ns
Arthritis type	Avascular necrosis	8.5 %	17.5 %	$p = 0.01$
	Osteoarthritis	87.7 %	69.2 %	$p < 0.0001$
	Atrophic	0 %	0.8 %	
	Normotrophic	84.3 %	63.3 %	
	Hypertrophic	3.4 %	5 %	
	Post-traumatic OA	0.4 %	1.7 %	ns
	Rheumatoid arthritis	0.9 %	0.8 %	ns
	Inflammatory arthritis	0.4 %	0.8 %	ns
	Other/not specified	2.1 %	10.0 %	
Anesthesia	General	8.5 %	10.8 %	ns
	Spinal	92.8 %	87.5 %	ns
	Epidural	80.9 %	9.2 %	$p < 0.0001$
	Spinal + epidural	80 %	5.8 %	$p < 0.0001$
	Regional block	13.6 %	68.3 %	$p < 0.0001$
	Femoral nerve	1.3 %	0.8 %	ns
	Sciatic nerve	0.4 %	0 %	ns
	Lumbar plexus	11.9 %	67.5 %	$p < 0.0001$
Operative duration		144 ± 40 minutes	142 ± 43 minutes	ns
Estimated blood loss		327 ± 232 ml	369 ± 239 ml	ns
Blood transfusion		7.7 %	13.3 %	ns
DVT prophylaxis	Overall	98.7 %	99.2 %	ns
	Fondaparinux	0.4 %	15.8 %	$p < 0.001$
	Aspirin	86.0 %	62.5 %	$p < 0.0001$
	Warfarin	11.1 %	10.8 %	ns
	Enoxaparin	11.1 %	42.5 %	$p < 0.0001$
	Clopidogrel	2.1 %	3.3 %	ns
	Heparin	0.4 %	3.3 %	ns
In-patient length of stay		2.69 ± 1.64 days	3.44 ± 2.09 days	$p = 0.0003$

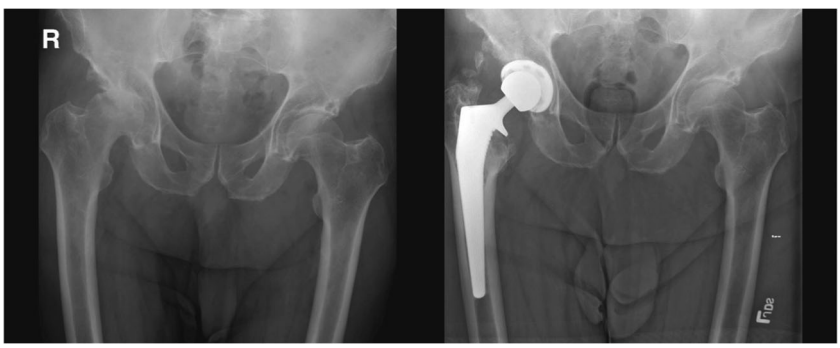

Fig. 1 Grade 3 heterotopic ossification representative radiographs of 76-year-old male who underwent anterior approach to total hip arthroplasty. Pre-operative radiograph is seen on the *left*. Post-operatively, this patient went on to develop the heterotopic ossification seen on the *right*

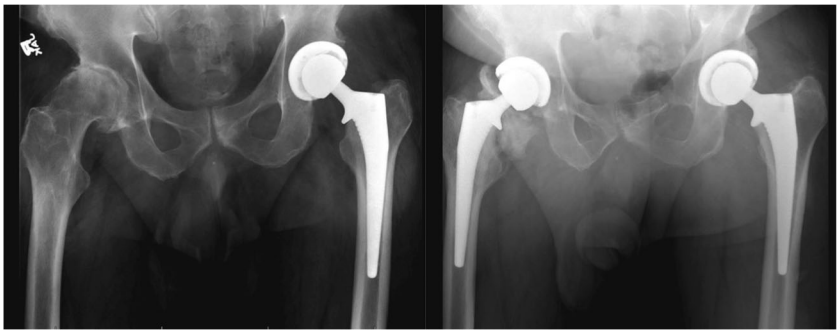

Fig. 2 Grade 4 heterotopic ossification representative radiographs of a 61-year-old male who underwent posterior approach to total hip arthroplasty. Preoperative radiograph is seen on the *left*. He previously had undergone left total hip without complication. Post-operatively, this patient developed the heterotopic ossification seen on the *right image*

osteoinductive and other growth factors [3]. These osteoinductive factors combined with osteogenic progenitor cells released from osseous reamings may induce the development of HO following THAs [3]. Heterotopic ossification typically develops during the 6 months following THA, and usually does not progress beyond that time period [7, 12].

Tippets et al. [10] published a retrospective radiographic review of the incidence of HO in 236 DAA THAs performed by three different surgeons in two different institutions. The overall incidence of HO following DAA in their study was 41.5 % (8.1 % Brooker grade 3 and 1.3 % Brooker grade 4). They concluded that the DAA does not protect against the development of HO when compared to other surgical

Table 3 Odds ratios for developing clinically significant heterotopic ossification

Variable	Comparison	Odds ratio (95 % CI)	*P*-value
Approach	Anterior approach	0.36 (0.13, 0.96)	0.041
Operative time	Per 10-min increase	1.004 (0.85, 1.18)	0.96
DVT prophylaxis	Fondaparinux	0.92 (0.11, 7.53)	0.94
	Aspirin	0.25 (0.09, 0.68)	0.0064
	Warfarin	4 (1.32, 12.5)	0.014
	Enoxaparin	2.38 (0.86, 6.67)	0.096
	Clopidogrel	7.1 (1.6, 33.3)	0.009
Blood loss	per 50-cc increase	1.05 (0.997, 1.12)	0.066
Gender	Female sex	0.38 (0.13, 1.10)	0.075
Age	5-year increase	1.20 (0.98, 1.46)	0.077
LOS	1-day increase	1.29 (1.12, 1.49)	0.0004
BMI	By 1-unit increase	0.98 (0.92, 1.05)	0.62
Race	AA vs white	1.27 (0.27, 5.85)	0.76
ASA status	ASA 1	NA	1
	ASA 2	0.32 (0.10, 0.99)	0.048
	ASA 3	4.17 (1.35, 12.5)	0.013
Transfusion	+Transfusion history	7.57 (2.49, 23.1)	0.0004
Medical comorbidities	Anemia	6.67 (1.25, 33.3)	0.026
	Cancer	1.19 (0.33, 4.35)	0.79
	Diabetes	0.68 (0.10, 4.76)	0.69
	GERD	0.78 (0.25, 2.50)	0.67
	CAD	4.76 (1.70, 12.5)	0.003
	Hypertension	1.47 (0.53, 4.17)	0.46
	Hyperlipidemia	1.09 (0.31, 3.49)	0.9
	Hypothyroidism	0.64 (0.08, 5.00)	0.67
	Sleep apnea	1.49 (0.33, 6.67)	0.6

approaches. Unlike their study, our study directly compared the incidence of HO in one surgeon's DAA and posterior approach to THA cohorts, limiting some of the operative variables that could have affected the results.

We also examined the association between the development of HO and several other variables. Consistent with results published in several other studies, we found that male gender was a significant risk factor for the *overall* development of HO [10, 13], but was not associated with the development of *clinically significant* HO in our study. In our study, race did not correlate with HO occurrence. Existing investigations have demonstrated no effect of bone mineral density on the development of HO after THA [14]. The association between age and the development of HO is debated in the literature. Eggli and Woo [15] examined 1,318 primary THAs for HO, and in their series, no significant association with age was identified. In our study, increasing age correlated with an increased overall incidence of HO, but not clinically significant HO. Body mass index (BMI) showed no association with HO in our cohort, in keeping with the data published by Tippets et al. [10]. In their review, Eggli and Woo found no significant association between height or weight and the development of HO [15]. The study presented here shows no significant relationship between development of HO and operative time. Toom et al. [8] performed a retrospective review of 178 patients who underwent THAs, and found the incidence of HO to significantly increase when the total operation time exceeded 100 minutes. There is existing data on the effect of NSAIDs on development of HO following THA. Brunnekreef et al. [16] demonstrated prospectively that a seven day course of a COX-2 inhibitor diminished the rates of HO after THA. None of their 42 patients receiving etoricoxib for seven days developed clinically significant (Brooker 3 or 4) HO at six months. Xue et al. [17] investigated existing literature regarding HO prophylaxis after THA with non-selective and COX-2 selective inhibitors, finding in total four randomized controlled trials. They document similar rates of HO prevention after THA between COX-2 and nonselective COX inhibitors, and conclude that the COX-2 inhibitors, with their lower gastrointestinal and other side effects, may be adequate.

In the present study, patients receiving dedicated NSAID or radiation prophylaxis against HO were excluded, but a number of our patients did receive anticoagulation with aspirin. Our results show that those patients receiving aspirin had a significantly lower incidence of grade 3 and 4 HO. Tippets et al. also found a significantly lower incidence of HO in patients who were given aspirin for DVT prophylaxis when compared to patients who were given warfarin [10]. Cohn et al. performed a retrospective review of 167 THAs comparing HO rates associated with aspirin versus warfarin for VTE prophylaxis [13]. In that study, patients who received aspirin had a significantly lower incidence of HO compared to patients who received warfarin. To date, there is no other study examining the relationship between clopidogrel and the incidence of HO.

Several studies have shown that the surgical approach used in THAs influences the incidence of HO after THA. Eggli and Woo found the anterolateral approach to THA to be a significant risk factor for the development of HO [15]. Pavlou and colleagues compared the incidence of HO after lateral THAs versus posterior THAs, and found that the lateral approach predisposes patients to the development of HO [18]. Similarly, Morrey and colleagues found the incidence of HO to be lower with a posterior approach than with an anterolateral or lateral transtrochanteric approach [19].

There are some limitations to our study. The study is limited by the retrospective design. Specifically, patients were not randomized to either of the surgical approach arms, and a potential selection bias exists. Lastly, radiographs were graded by only one observer in our study. Although the observer was blinded to subject cohort, inherent bias with only one observer still exists.

To date, only one other study has sought to determine the overall incidence of HO after DAA THAs. Furthermore, no study has directly compared the incidence of HO following DAA THAs to the incidence of HO following posterior THAs performed by a single surgeon. This study expands the limited data available on the incidence of HO following DAA THAs. Our study shows a decreased incidence of clinically significant HO in patients who underwent a DAA when compared to posterior THAs. This may be instructive when approaching THA candidates with conditions that predispose them to the development of HO, such as hypertrophic OA or ankylosing spondylitis.

Compliance with ethical standards

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Conflict of interest The authors have no relevant conflict of interest with regard to this study to declare.

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