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Original Research

Preoperative Predictors of Soft Tissue Releases Required for Femoral Exposure in Direct Anterior Total Hip Arthroplasty

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ABSTRACT

Background: Sequential soft tissue releases are utilized in direct anterior approach (DAA) total hip arthroplasty (THA) as incomplete femoral exposure may lead to complications. This study identifies patient-specific parameters associated with soft tissue releases required for femoral exposure.
Methods: A retrospective review was conducted on 133 patients (150 hips) who underwent primary THA via DAA with a single surgeon. Preoperative radiographic measurements included ilium-ischial ratio (IIR), anterior superior iliac spine to tip of the greater trochanter (AGT), femoral neck-shaft angle (FNA), and articulotrochanteric distance (ATD). Operative reports were reviewed and a multinomial logistic regression model was conducted to identify associations of soft tissue releases.
Results: Among patients, 12 (8%) had no release, 94 (62%) had conjoined release, 44 (29%) had conjoined and piriformis releases. Multivariate analysis revealed IIR (OR [odds ratio] 1.68, $P = .008$), right laterality (OR 7.41, $P = .025$), and body mass index (BMI) (OR 1.26, $P = .041$) were associated with conjoined release. BMI (OR 1.51, $P = .001$), right laterality (OR 7.63, $P = .038$), and IIR (OR 2.06, $P = .001$) were also associated with piriformis release. There were no statistically significant differences between AGT, FNA, or ATD between groups.
Conclusions: Patients with increased ilium to ischial ratio, right laterality, and larger BMI were associated with greater number of soft tissue releases for adequate femoral exposure. Surgeons may consider these factors to anticipate femoral releases or challenging femoral exposure in direct anterior total hip arthroplasty.

Introduction

The volume of total hip arthroplasty (THA) has risen substantially and is projected to grow 176% by 2040 and 659% by 2060 [1]. In recent years, the direct anterior approach (DAA), through the Smith-Petersen interval, has gained substantial popularity [2,3]. Although the DAA has seen increased utilization, this approach has been associated with a higher risk of femoral complications and difficulty with femoral exposure [3-6].

Incomplete femoral canal exposure may lead to difficulty with femoral preparation, component malposition, or periprosthetic fracture [7,8]. Sequential soft tissue release techniques have been described to offer better femoral exposure and to help mitigate complications [9]. Previous literature has described that the recommended stepwise order of releases are: (1) release of the superior-posterior capsule off the femur; (2) release of the conjoined tendon; (3) release of the piriformis; and (4) release of the obturator externus (rare) [9-11]. Most patients have adequate femoral exposure with the first 2 steps; however, for more challenging cases, release of the piriformis may be required. Posterior external-rotator structures are generally the last to be released and are considered secondary releases, as they assist with posterior and lateral stability of the hip, have been associated with increased postoperative pain, and provide a notable checkrein to dislocation [10,12,13].

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With increasing numbers of THA through the DAA, understanding risk factors associated with challenging femoral exposure is increasingly important. Prior studies have demonstrated patient-specific anatomical parameters are important predictors of femoral fracture, operation time, and overall complication rate [8,14,15]. It is hypothesized that short varus femoral necks or wider pelvises, in which the ilium may overhang the proximal part of the femur, may increase surgical complexity, primarily through making femoral exposure more challenging [11,14-17]. However, there are no studies to date describing the association between patient risk factors and soft tissue releases required for femoral exposure in DAA. This information would assist the surgeon in anticipating a challenging femoral exposure and provide an opportunity for improved preoperative planning.

The primary purpose of this study was to identify patient-specific radiographic parameters associated with the number of soft tissue releases required during femoral exposure to DAA. The secondary goal of this study was to describe the patient characteristics associated with the number of soft tissues required during femoral exposure.

Material and methods

Study design

After institutional review board approval, a retrospective, single-surgeon cohort study of consecutive primary THAs performed at a single, large academic center between July 2021 and December 2023 was conducted. Patients were excluded if THA was performed for conversion of prior hip surgery, fracture, or approach other than DAA. In the present study, 133 patients (150 hips) who underwent elective, primary THA via DAA for the treatment of osteoarthritis were included, and their clinical records were retrospectively investigated. A full chart review of each patient was performed in order to obtain demographic variables of age, sex, and body mass index (BMI) at the time of surgery. The operative reports were reviewed to obtain variables related to the surgery including soft tissue (superior capsule, conjoined, piriformis, and obturator externus tendons) release during femoral exposure and operative time. The cohort consisted of 55.3% men and 58.7% right hips with mean age of 60.7 years (range, 33-82) and BMI of 30.0 (range, 19.3-41.2), respectively (Table 1).

Table 1
Patient characteristics.

Variable	Means (SD) or percentage (N)
Age	60.7 (10.4) Range 33-82
Sex (male)	55.3% (83)
BMI	30.0 (4.8) Range 19.3-41.2
Laterality (right)	58.7% (88)

Surgical procedure

Patients were placed supine on an orthopaedic positioning table (Hana Orthopedic Surgery Table, Mizuho OSI, Union City, CA). A standardized DAA was used on all hips by a single fellowship-trained orthopaedic surgeon. The incision was marked out 2 cm lateral and distal to the anterior superior iliac spine and extended longitudinally in line with the fibers of the tensor fascia lata muscle. The fascia was then incised and elevated off the tensor fascia lata, intermuscular plane identified, and retractors were placed to expose the hip capsule. Using electrocautery, a capsulotomy was performed in line with the femoral neck and then the femoral shaft dividing the capsule at a 135° angle. Both inferior medial and superior capsular flaps were then tagged with suture. Cautery was then used to dissect the inferior capsule down to the lesser trochanter inferomedially while the leg was externally rotated to 90 degrees, which initiated the release of the pubofemoral ligament and the eventual 270-degree capsulotomy. Femoral neck cut was then made under fluoroscopy, and the acetabulum was prepared.

During femoral exposure, the femoral hook attachment to the Hana table was placed underneath the femur, distal to the vastus ridge. The leg was externally rotated to 140 degrees. A double-pronged Mueller retractor was then placed distally and medially over the calcar, and complete release of the remaining pubofemoral ligament and posterior capsule at the level of the neck cut was performed. The leg was then extended and adducted. A retractor was then placed posteriorly between the superolateral capsule and gluteus minimus. The superolateral capsule was released off the femur in all patients, allowing for improved elevation of the femur. At this point, if femoral exposure was inadequate, then the conjoined tendon was released while taking care not to release the piriformis tendon, obturator externus, or abductor insertions on the greater trochanter. If more exposure was necessary, then a “reset” of the femur was done by bringing the leg back to neutral with replacement of the retractors (Fig. 1a). If more exposure was necessary after a reset, the piriformis tendon was released, taking care not to release the abductors. Obturator externus was not released in any of our cases but would have been released had exposure remained inadequate following piriformis release (Fig. 1b). These releases were performed in a sequential manner, as shown in Figure 2 [9]. A single-offset, automated impactor broach handle was utilized for canal preparation and eventual insertion of a cementless, hydroxyapatite-coated triple-tapered collared femoral stem.

Radiographic measurements

Morphological parameters of interest were assessed on preoperative standing anteroposterior radiographs of the hips and pelvis using previously validated digital software (Phillips IntelliSpace PACS Enterprise Version 4.4, Andover, MA) [8]. Two observers (orthopaedic surgery residents), blinded to outcome, ie, soft tissue release or not, performed all radiographic measurements. Radiographs were calibrated using a 25-millimeter radiographic marker or a radiopaque extremity ruler.

Pelvic geometry was analyzed using previously described radiographic parameters including ilium-ischial ratio (IIR), distance from anterior superior iliac spine to the tip of the greater trochanter, femoral neck-shaft angle, and the articulo-trochanteric distance (ATD) [8,18]. All measurements have been previously described and have demonstrated both intra- and inter-rater reliability [8,18,19]. Each of these measurements can be obtained on the anteroposterior pelvis radiograph (Fig. 3, Fig. 4, and Fig. 5).

The IIR is measured as the ratio between the distance of the most prominent aspects of the ilium to the most prominent aspects of the ischium. The femoral neck-shaft angle depicts where in the coronal plane the femoral head lies in relation to the anatomic axis of the femur. The apex of the angle lies at the intertrochanteric line and is at the intersection of a line down the femoral canal and a second line parallel to the neck of the proximal part of the femur. ATD is measured by drawing a line parallel to the femoral shaft, then drawing a line perpendicular at the tip of the greater trochanter and another at the superior aspect of the femoral head.

Data analyses

Continuous variables are represented as means and standard deviations. Categorical variables are represented as percentages

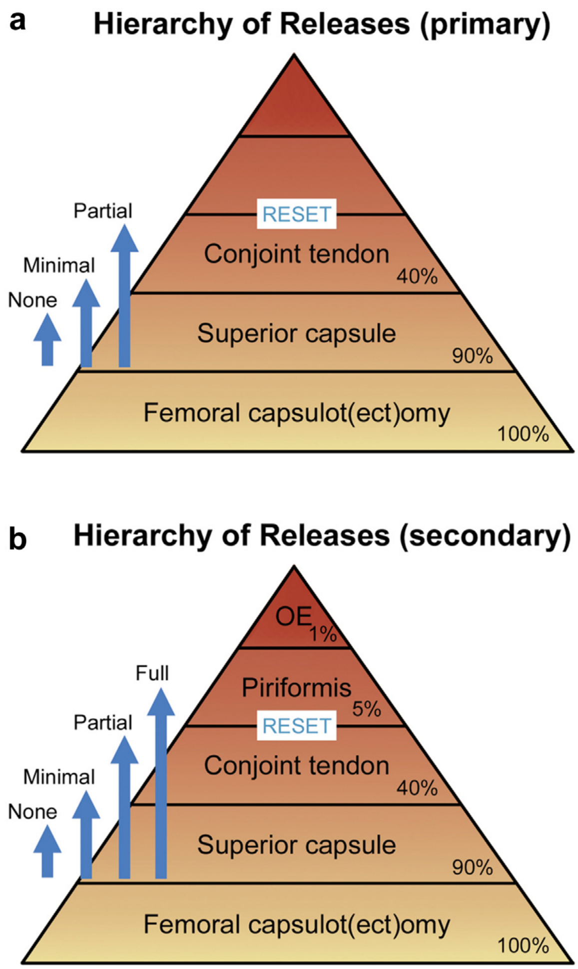

Figure 1. Hierarchy of (a) primary releases and (b) secondary releases. Minimal, partial, and full refer to the amount of release generated about the saddle of the greater trochanter. Figure courtesy of and used with permission from Chughtai et al [9].

and absolute numbers. For univariate comparisons, one-way ANOVAs with Tukey post-hoc tests are used to assess differences between groups on continuous variables and chi-square tests of independence or Fisher exact tests to assess differences between groups on categorical variables. A multinomial logistic regression model was conducted assessing factors associated with likelihood of conjoined release and factors associated with likelihood of conjoined plus piriformis release with the no release set as the reference group. An alpha level is set at $P = .05$ for all assessments. SPSS version 29 (IBM, Inc., Chicago) was used for all analyses. A post-hoc power analysis was conducted using difference of means based on IIR. The achieved power $(1 - \beta) = 0.998$, indicating a sufficient sample size.

Results

Univariate analysis

There were 94 (62%) hips that had conjoined release, 44 (29%) hips had conjoined and piriformis releases, and 12 (8%) hips had neither conjoined nor piriformis releases (superolateral capsule release only) (Table 2). Univariate analysis was performed to assess differences between these groups and can be seen in Table 2. Male sex, BMI, procedure duration, and ischial width were found to be associated with conjoined and piriformis release (P =< 0.01) (Table 2). Right laterality was statistically significant for both soft tissue releases when compared to the no release group ($P = .047$). Our study included a single right-handed arthroplasty-trained surgeon. There was no statistically significant difference between laterality when comparing the conjoined only and conjoined plus piriformis release groups. Increasing IIR was associated with increased releases (P =< 0.001). There were no statistically

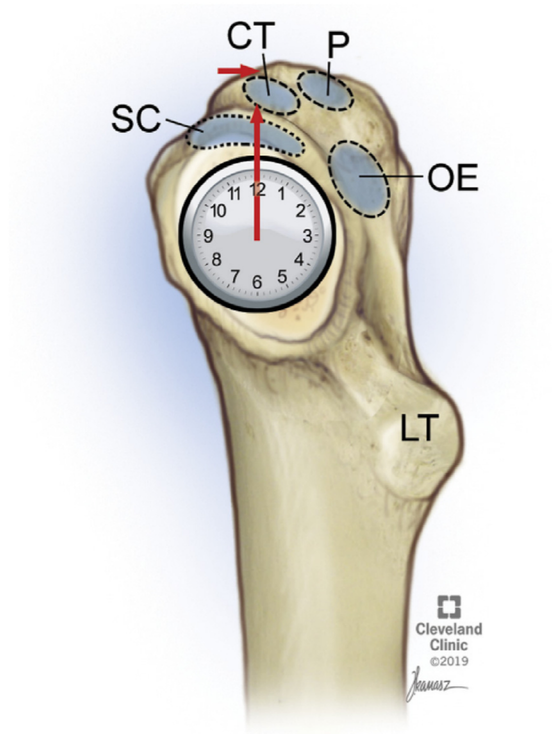

Figure 2. Releases performed in a clockwise direction in relation to the right hip. SC, superior capsule; CT, conjoint tendon insertion; P, piriformis tendon insertion; OE, obturator externus tendon insertion; LT, lesser trochanter. Figure courtesy of and used with permission from Chughtai et al [9].

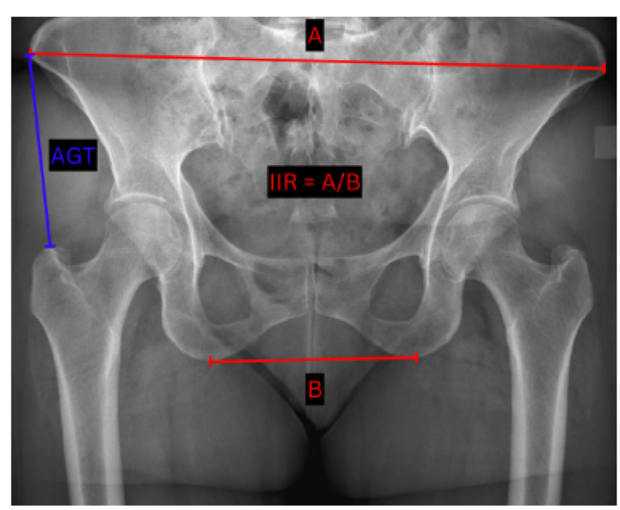

Figure 3. Measurements of ilium width (a), ischium width (b), ilium-ischial ratio (IIR) = a/b, and ASIS to greater trochanter distance (AGT). ASIS, anterior superior iliac spines.

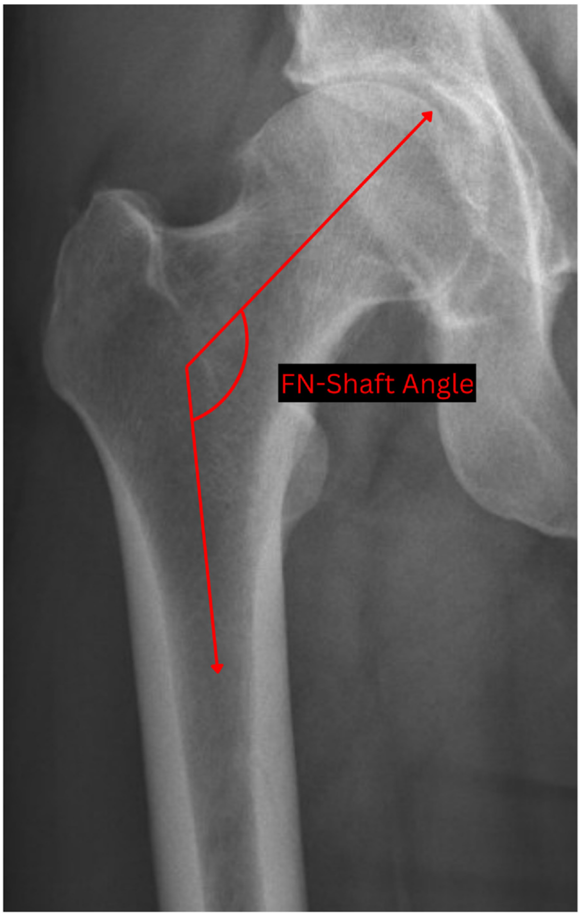

Figure 4. Femoral neck shaft angle (FNA).

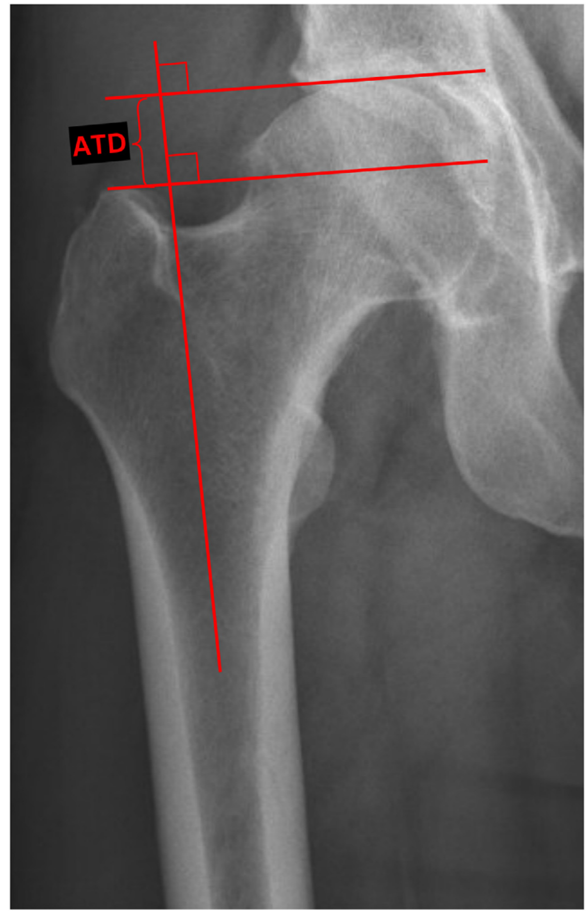

Figure 5. Articulo-trochanteric distance (ATD).

significant differences between age, anterior superior iliac spine to the tip of the greater trochanter, femoral neck-shaft angle, or ATD between the 3 groups (Table 2).

Multivariate analysis

Variables identified to be risk factors for increased soft tissue release were selected for the multivariate model. This model analyzed variables with the strongest statistical significance and can be seen in Table 3. BMI (odds ratio [OR] = 1.26 [1.01-1.57]; P = .041), right laterality (OR = 7.41 [1.29-43.48]; P = .025), and IIR (OR = 1.68 [1.14-2.47]; P = .008) were associated with conjoined release. BMI (OR = 1.51 [1.19-1.92]; P = .001), right laterality (OR = 7.63 [1.12-52.63]; P = .038), and IIR (OR = 2.06 [1.35-3.13]; P = .001) were associated with increased likelihood of combined conjoined and piriformis releases.

Discussion

Over the past decade, the DAA to THA has emerged as a popular technique among joint replacement surgeons. This technically demanding approach is known to carry a steep initial learning curve secondary to its small incision, tight intermuscular planes, and unique operating table and setup [9]. Femoral exposure, particularly in obese patients, is especially challenging with inadequate femoral exposure leading to component malposition and fracture [14]. To combat these technical challenges, several authors have advocated for an algorithmic approach to the soft tissue releases required to deliver the proximal femur into the wound [11,20]. At present, there is no reliable means of anticipating the required soft tissue releases preoperatively. Rather, the extent of release is decided in real time based on intraoperative femoral external rotation and ventral translation.

As computerized templating, robotic assistance, and artificial intelligence become mainstays in the orthopaedic arena, understanding the likelihood of intraoperative events using preoperative radiographic data is invaluable. Fortunately, the preoperative evaluation of pelvic radiographs is already a well-established practice in the field of arthroplasty. While there has been a long-accepted gestalt among arthroplasty surgeons that certain constellations of pelvic and proximal femur anatomy seen on preoperative pelvis radiographs will make for a more challenging case, naming and quantifying these parameters has proven to be more difficult.

Several previous studies have attempted to link preoperative radiographic parameters with surgical duration, complications, and outcomes. A 2016 investigation by Sang et al. retrospectively analyzed the clinical and radiographic data of 124 direct anterior total hip arthroplasties to reveal that lower BMI, a larger ratio of the distances between greater trochanters and anterior superior iliac spines, and the vertical distance between the anterior superior iliac spines and greater trochanters were associated with shorter operative times, less blood loss, and lower complication rates [14]. It is noteworthy that the group's indications for arthroplasty were heterogeneous with the majority performed for fracture, followed by avascular necrosis, osteoarthritis, and rheumatoid arthritis. More recently, McGoldrick et al. found that elevated IIRs and

Table 2
Comparisons of patient characteristics and preoperative and postoperative radiographs for both conjoined release and for piriformis release following THA (N = 150).

Variable	No release N = 12	Conjoined release N = 94	Conjoined + piriformis release N = 44	*P*-value
Age	60.8 (12.7)	61.4 (10.1)	59.1 (10.3)	*P* = .470
Sex (male)	25.0% (3)[a]	50.0% (47)[a]	75.0% (33)[b]	***P* = .002**
BMI	26.4 (3.4)[a]	29.1 (4.2)[a]	32.9 (5.0)[b]	***P* < .001**
Laterality (right)	25.0% (3)[a]	61.7% (58)[b]	61.4% (27)[b]	***P* = .047**
Procedure duration	99.3 (14.8)[a]	108.1 (14.6)[a]	118.8 (19.4)[b]	***P* < .001**
Ilium width (mm)	271.5 (22.5)	278.6 (20.8)	281.5 (26.3)	*P* = .399
Ischial width (mm)	106.9 (11.9)[a]	99.2 (10.9)[a]	94.2 (13.2)[b]	***P* = .002**
Ilium-ischial ratio	2.56 (0.26)[a]	2.83 (0.27)[b]	3.02 (0.34)[c]	***P* < .001**
ASIS to GT (mm)	102.3 (13.7)	96.8 (14.6)	94.4 (13.4)	*P* = .233
FN angle (deg)	131.3 (3.7)	130.5 (4.5)	131.7 (6.0)	*P* = .361
ATD (mm)	21.1 (4.8)	21.6 (17.2)	22.1 (12.0)	*P* = .979

ASIS, anterior superior iliac spines; GT, greater trochanter; FN angle, femoral neck angle.
The same letter in a row (a, b, or c) indicates no significant difference. Data with different letters in each row differed significantly. If there are no letters, they were not different from either of the other groups. Bold values indicate statistical significance ($P < .05$).

femoral canal flare indexes on preoperative pelvic radiographs increased the risk of early periprosthetic femur fracture in 39 fractures matched with 78 nonfracture controls [8].

While our study excluded patients with hip dysplasia, Tamaki et al. retrospectively evaluated the radiographic parameters of 204 dysplastic hips to find that proximal migration and lower position of the femoral head relative to the greater trochanter were associated with increased surgical durations [15]. In 2023, Free et al. found that a decreased neck-shaft angle and lower preoperative leg-length discrepancy predicted malposition of the femoral stem in the coronal plane [17]. Most recently, Rizk et al. challenged the clinical relevance of these findings by showing that multiple radiographic parameters for pelvic and proximal femoral morphology in patients undergoing anterior hip replacements did not predict outcomes [19].

Our study revealed that the preoperative parameters of increased IIR, increased BMI, and right laterality were associated with additional femoral soft tissue releases. Appreciating these associations stands to improve a surgeon's ability to anticipate the extent of required intraoperative soft tissue releases before ever entering the operating room. Specifically, for each unit increase in BMI, the likelihood of conjoined release and piriformis release increased by 26% and 51%, respectively. For each one-tenth unit increase in IIR, the likelihood of conjoined release and piriformis release increases by 68% and 106%, respectively. Interestingly, right-sided hips had a 7.4 and 7.6 times greater likelihood of conjoined release and piriformis release, respectively. While this result is difficult to explain, one possibility is that all cases in this study were performed by a single fellowship-trained arthroplasty surgeon who is right-handed and possibly benefited from additional soft tissue releases on right-sided hips. While a single surgeon study minimizes the variability in soft tissue release preferences and operative techniques, the findings are less generalizable.

This study was focused solely on radiographic correlates with specific soft tissue release requirements for adequate femoral exposure. In our cohort, 29% of patients underwent piriformis release, which is on par with current literature, which reports piriformis releases in 25%-57% of DAA THA patients [20,21]. Currently, no literature has described clinical outcomes or consequences of increased releases through this approach. Further research is currently underway on this cohort to evaluate the specific patient outcomes and complications, if any, based on the extent of soft tissue releases required. Additional limitations include the retrospective nature of the study, which makes it vulnerable to unmeasured confounding factors. Furthermore, although our sample

Table 3
Multinomial logistic regression analysis to determine the key factors associated with conjoined release and with conjoined + piriformis release, with no release as the reference group.

Variable	B	SE	*P*-value	Odds ratio	95% lower CI	95% upper CI
Conjoined release						
Age	.008	.037	.824	1.008	.938	1.084
Sex (male)	.437	.971	.656	1.548	.226	10.586
BMI	.231	.113	**.041**	1.260	1.009	1.573
Laterality (right)	2.005	.892	**.025**	7.407	1.292	43.478
Procedure duration	.034	.033	.306	1.035	.969	1.104
IIR (adjusted)	.519	.196	**.008**	1.680	1.144	2.467
ASIS to GT (mm)	−.013	.027	.662	.987	.936	1.041
FN angle (deg)	.000	.106	.998	1.000	.813	1.231
ATD (mm)	.017	.033	.599	1.017	.954	1.085
Conjoined + piriformis release						
Age	−.011	.042	.791	.989	.912	1.073
Sex (male)	.285	1.097	.795	1.329	.155	11.412
BMI	.413	.123	**.001**	1.511	1.186	1.924
Laterality (right)	2.032	.980	**.038**	7.633	1.117	52.632
Procedure duration	.053	.036	.136	1.054	.983	1.131
IIR (adjusted)	.722	.213	**.001**	2.058	1.355	3.126
ASIS to GT (mm)	−.018	.030	.542	.982	.926	1.041
FN angle (deg)	.018	.037	.622	1.018	.948	1.094
ATD (mm)	.018	.037	.622	1.018	.948	1.094

ASIS, anterior superior iliac spines; GT, greater trochanter; SE, standard error; CI, confidence interval.
Bold indicates statistical significance $P \leq .05$.

of 150 hips is on par with similar studies on this topic, a larger number of patients would have increased our power to detect more subtle, additional associations with intraoperative soft tissue releases. Lastly, it is important to acknowledge that the radiographic measurements recorded in this study do not capture differences in patient body habitus or preoperative range of motion, which are also key barriers to adequate femoral exposure.

Conclusions

The results of this study demonstrate that increased IIR, right laterality, and increased BMI were associated with challenging femoral exposure requiring additional femoral soft tissue releases. Arthroplasty surgeons may consider these factors during preoperative planning to anticipate challenging femoral exposure during direct anterior THA.

Conflicts of interest

C. C. Green is a reviewer of the Journal of Arthroplasty and is a member of the AAHKS Patient Education Committee. G. J. Haidukewych receives royalties from Depuy Synthes and Zimmer Biomet; is a paid consultant for Depuy Synthes, Zimmer Biomet, and Smith and Nephew; has stock options in Selenic; receives research support from Smith and Nephew; and has fellowship support from Depuy Synthes and Smith and Nephew. All other authors declare no potential conflicts of interest.

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CRediT authorship contribution statement

Michael S. Barnum: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Bryan M. Grommersch:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Samuel Hovland:** Writing – review & editing, Project administration, Methodology, Investigation, Data curation, Conceptualization. **George J. Haidukewych:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Cody C. Green:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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