Outcomes Following the Single-Incision Anterior Approach to Total Hip Arthroplasty: A Multicenter Observational Study

The Anterior Total Hip Arthroplasty Collaborative (ATHAC) Investigators

KEYWORDS

• Single incision • Anterior approach
• Total hip arthroplasty • Quality of Life
• Function • Outcomes • Technique

Osteoarthritis, the clinical syndrome of joint pain and dysfunction caused by joint degeneration, affects more people than any other joint disease. This burden has been recognized by the United Nations and World Health Organization by endorsing the Bone and Joint Decade 2000–2010. Osteoarthritis disables approximately 10% of people who are older than 60 years, compromises the quality of life of more than 20 million Americans, and costs the United States economy more than $60 billion per year.[1]

Less invasive approaches have become the focus in arthroplasty, with special approaches and specifically designed instruments to accommodate such approaches. The keywords "minimally invasive surgery" in the medical database PubMed retrieves over 12,000 articles on this topic, of which 11,000 have been published in the past 2 years. An Internet search (Google) reveals over 90,000 hits on "minimally invasive hip surgery," of which 50% have occurred in the past 2 years.

Commonly reported single-incision less-invasive techniques include the anterior approach, the mini-Watson-Jones approach, the trochanteric flake technique, and the miniposterior and mini-posterolateral approaches.[2–9] Dual-incision approaches incorporate two mini-incisions (one anterior-based and one posterior-based).[4,5] This relative explosion of information has further confused the subject matter. Few large series and few small trials exist to provide patients and surgeons sufficient evidence to guide their treatments.

Among these approaches, the direct anterior, intermuscular approach to the hip has several

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potential advantages, including preservation of muscle attachments to bone, improved dynamic hip stability, and decreased risk of hip dislocation after surgery.[10–14] The first hip arthroplasty performed through this approach was by Robert Judet in 1947 at Hospital Raymond Poincare in Garches, outside Paris. A Judet acrylic prosthesis was implanted. Judet referred to the surgical approach as the "Hueter Approach." The anterior intermuscular approach has been the subject of two very large observational cohort studies.[10–13] Siguier and colleagues[10] have reported on a series of 1,037 patients treated with the anterior approach to total hip arthroplasty (THA) with an orthopedic table. Keggi and colleagues[11] have also reported a series of 2,132 primary THAs performed via the anterior approach to THA, but without the specific aid of an orthopedic table.[12] Keggi's study reported a dislocation rate of 1.3% and excellent early patient function. Whether the results of this muscle-sparing approach can be extrapolated to surgeons with less experience remains unknown when compared to posterior-muscle splitting or lateral-abductor splitting approaches.

The Anterior Total Hip Arthroplasty Collaborative (ATHAC) is a multicenter research group with an interest in cooperative research toward improving knowledge about the surgical technique (for a list of ATHAC members, see Appendix 1). The current study was conducted to determine outcomes following elective THA using the anterior surgical approach.

METHODS

The investigators conducted a multicenter cohort study of 1,152 patients across nine clinical sites across the United States, evaluating complications and function associated with the anterior approach to THA. The study was coordinated and data analyzed by an independent methods center outside the United States (**Fig.1**). This study was conducted by ATHAC.

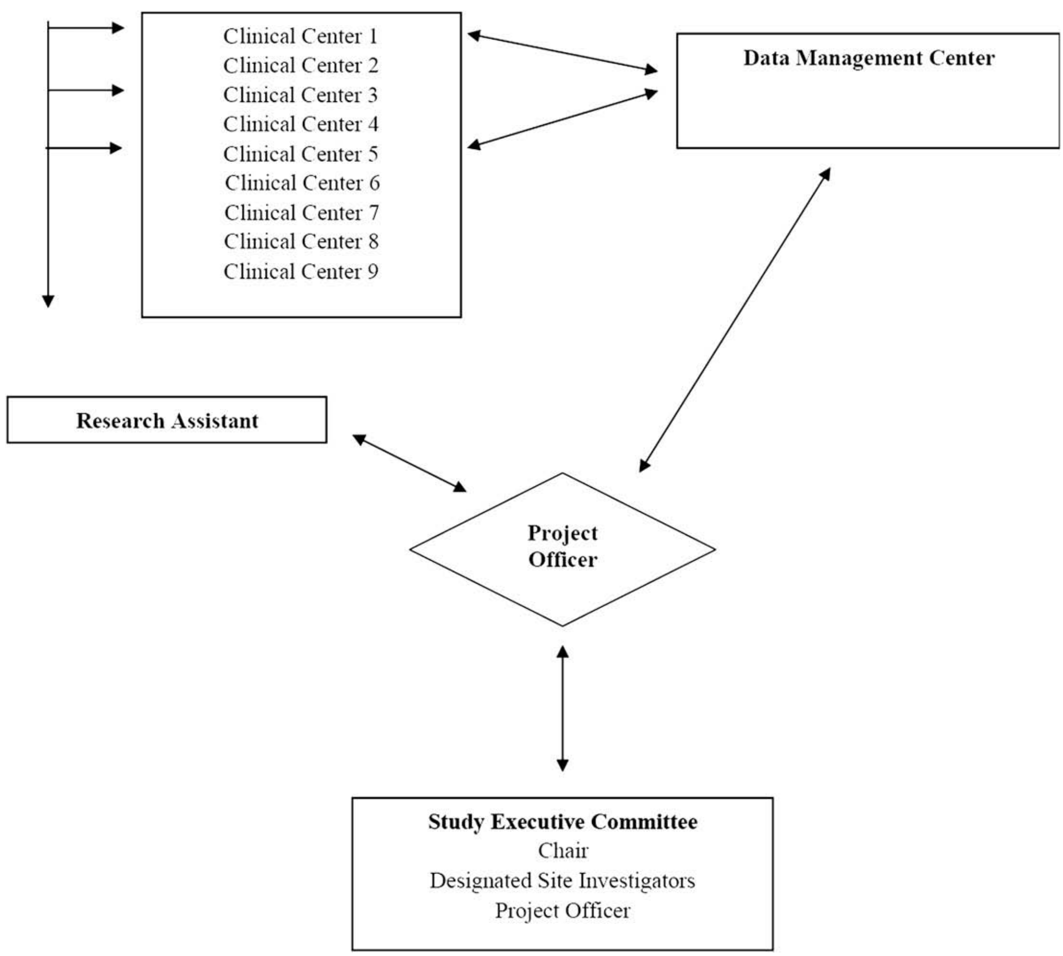

Fig. 1. Study organization.

Eligibility Criteria

Patients were considered to be eligible for the study if they were adults admitted with a primary diagnosis of hip arthritis (ie, diagnosis confirmed radiographically and clinically) and, as a result, were operatively managed with the anterior approach to THA. Patients managed with alternative approaches, revision arthroplasty, and those patients with inadequate records were excluded.

Intervention

Briefly, after administration of general or regional anesthesia, the patient is placed in the supine position on an orthopedic table (eg, Tasserit table, OSI ProFX, or HANA table). The normal incision starts 2-cm to 3-cm posterior and slightly distal to the anterior superior iliac spine. This straight incision extends in a distal and slightly posterior direction to a point 2-cm to 3-cm anterior to the greater trochanter. After incision of the skin and subcutaneous area, the tensor can be seen through the translucent fascia lata. The fascia lata is incised over the tensor and continued distal and proximal to the ends of the skin incision. The sartorius and rectus femorus muscles are retracted medially with a cobra retractor. The lateral femoral circumflex vessels are identified as they cross the distal portion of the wound. These vessels are clamped, cauterized, and transected. The hip capsule is incised and the hip joint is exposed. Details of the full surgical technique are presented in Appendix 2.

Case Report Forms

The investigators collected information about the patients, implants, and procedure. The patient's date of birth, gender, ethnicity, occupation, height, weight, body mass index (BMI), comorbidities (ie, cardiovascular, respiratory, psychiatric, neurologic, genitourinary, gastrointestinal, musculoskeletal, previous lower extremity surgery, and so forth), American Society of Anesthesiologists (ASA) classification, and preoperative diagnosis (ie, osteoarthritis, avascular necrosis, rheumatoid arthritis, septic osteoarthritis, posttrauma, ankylosing spondylitis) were recorded for each patient to provide a depiction of the patient population studied. The following surgical information was abstracted from each patient's medical records: side of hip surgically treated, age at surgery, whether the surgery was a primary THA or if there was a previous surgery on the affected hip, the surgical technique used (ie, length of incision, operative duration, C-arm total time, and other factors), type of anesthesia (ie, general or regional), the estimated blood loss, the acetabular cup position (ie, acetabular inclination/abduction and acetabular anteversion), and the leg-length discrepancy (ie, shorter, longer, or none). Each patient's acetabular and femoral implant information was recorded. Characteristics, such as if bone grafting of the acetabulum was performed, the acetabular implant outer and inner diameter, liner, type (ie, cemented or press-fit), company, and brand were collected, as well as the femoral implant's head and stem size, neck angle, type, and company and brand.

Outcomes

Given the study design, not all study outcome measures were collected at each participating site. Outcomes available at all participating sites included the number of postoperative days in the hospital, the patient's disposition following discharge from the hospital (ie, home, rehabilitation center, aging and long-term care, skilled nursing facility, none), any assistive devices given at discharge and the time it took the patient to discard the assistive devices, revision surgeries, and complications. Outcomes available at few sites included functional outcome indices, such as the Western Ontario McMaster Osteoarthritis index (WOMAC).[15] The investigators varied and reported the denominator for each reported outcome as appropriate.

Data Collection

Data abstraction was conducted using one of two methods. The majority of the centers retained all patient information in personal and medical records. There were a few clinical sites that recorded all information into an electronic database. Each patient's demographic, surgical, and outcome data was recorded using study-specific case-report forms (CRFs).

Seven of the nine participating centers elected to have their own research staff complete the data abstraction. CRFs were shipped to each site and any questions regarding the data abstraction process or completion of CRFs were addressed with regular site contact by the methods center coordinator. Upon receipt, completed patient CRFs were reviewed by the methods center coordinator for missing or inconsistent values. Three centers required site visits by the methods center coordinator to assist with CRF completion.

Pilot Testing and Site Visits

Before the administration of the CRFs to all participating centers, the methods center coordinator conducted a pilot data-abstraction site visit to one of the clinical centers. A random sample of 100 patient records were abstracted; 84 patients were found to be eligible and 16 were excluded. The piloted CRFs were revised to include patients that underwent bilateral THA, data points were rearranged to make data abstraction as painless as possible, and other minor changes were also implemented.

Data Analysis

Sample size calculation

To have sufficient sample size to conduct regression analyses exploring baseline variable association (n = 10) with the presence or absence of complications, the investigators required approximately 100 events (ie, 10 events per variable included in the analysis). Given a plausible complication rate of 10%, the investigators required at least 1,000 patients for the study. The sample size was further adjusted to account for ineligible charts (20%). Thus, 1,200 patients was a reasonable sample size to assure sufficient study power (80%) for the regression analysis.

The investigators further planned to compare outcomes among surgeons with 100 or fewer cases with surgeons with greater than 100 cases. If one anticipates a learning curve in complication rates, it remains plausible that a 40% reduction in complication risk could occur over and after the first 100 cases. The investigators assumed a 10% baseline complication risk and thus a reduction from 15% to 9% constituted a 40% reduction in risk. Assuming an alpha = 0.05, and a study power = 0.80, 460 patients were required per arm of the study.

Statistical analysis

The investigators reported baseline patient characteristics as mean and standard deviations (SD) (or median and interquartile range, if the data were skewed) for continuous data, and proportions and percentages for categorical data. Independent sample t-tests were conducted for continuous data and chi-square for categorical data to compare the baseline characteristics (ie, across less and more experienced surgeons). P-values were corrected for multiple testing when multiple tests of association were conducted.

A regression analyses was conducted to evaluate variables associated with patient complications, pain and function, and days in hospital. Univariable analyses were conducted and those variables that revealed association (at the $P<0.1$ level) were entered into a multivariable model. Logistic regression with odds ratios and their associated 95% confidence intervals were reported.

RESULTS

Study Population

Across nine participating sites, 1,152 eligible patients who underwent a total of 1,277 THAs using the anterior approach were identified (**Fig. 2**). Patients were a mean age 65 years, predominantly Caucasian, with a mean BMI of 28. The majority of patients had a preoperative diagnosis of osteoarthritis. One hundred twenty-five patients underwent bilateral hip arthroplasty (**Table 1**). Across centers, patients did not differ by gender or BMI; however, there were differences in mean patient age ($P<0.01$) and ASA class ($P<0.001$) across centers.

Technical Aspects of Surgery

Surgeons operated on patients for an average 95 minutes, with a mean-incision length under 10 cm and 30 seconds of fluoroscopic time (**Table 2**). A variety of implant vendors were used, with almost all surgeons using a press-fit femoral stem (**Table 3**). The bearing surface was most commonly a metal on cross-linked polyethylene (**Table 4**). The most common femoral head sizes used were 28 mm (39.8%) and 32 mm (50.3%). Leg length discrepancy averaged 0.4 cm.

Hospital Stay and Assistive Devices

Patients were in hospital for a mean 3.6 days, with the majority discharged to home (82.6%) (**Table 5**). All but 24 patients used an assistive device at discharge from hospital. The most common devices were walkers and crutches (see **Table 5**). Assistive devices were discontinued at a mean 21 (median, 14) days; however, 80% of patients no longer used an assistive device by 4 days after hospital discharge.

Revision Surgery

Thirty-five patients required a reoperation after the index procedure (**Table 6**). Seventeen of the revisions were the result of aseptic loosening of the prosthesis. Of eight dislocations, three required implant revision (one liner, one femoral head, and one stem); five were treated with closed reduction in the operating room. Leg-length discrepancy required reoperation in three patients.

Regression analysis suggested a strong association between the need for revision surgery and surgeon (center effect) ($P<0.001$).

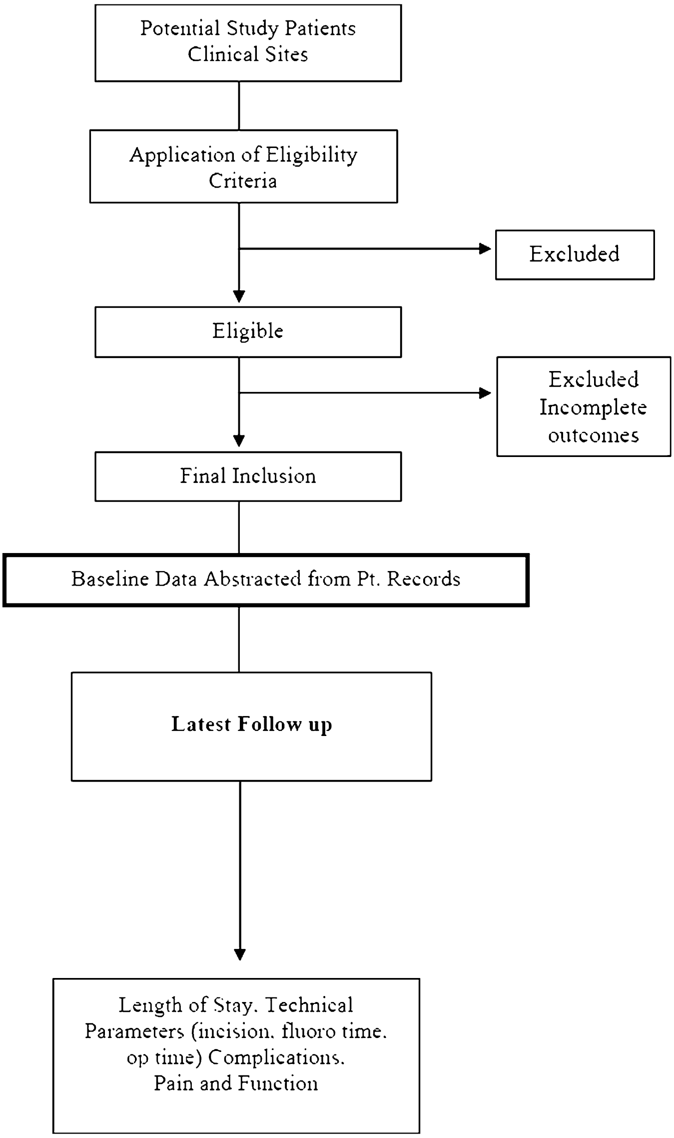

Fig. 2. Study flow.

Complications

Table 7 details both musculoskeletal and general medical complications. Twenty patients experienced cardiovascular complications, 3 psychologic, 8 neurologic, 27 wound-related, 6 genitourinary, and 36 miscellaneous (anemia, nausea, edema, hypokalemia). One patient died in the study cohort of 1,152 patients.

Regression analysis suggested significant associations between the presence of a complication and three variables: length of hospital stay (odds ratio = 1.2, $P<0.001$), BMI (odds ratio = 1.1, $P = 0.05$), and surgeon/center (odds ratio = 1.3, $P = 0.01$).

The investigators further compared surgeons with 100 or greater case experience (total patients included, 842) versus those with less than 100 case experience (total patients included, 435) on complication rates. Surgeons who had performed less than 100 cases were twofold more likely to have complications in their patients (20.2% versus 9.8%, $P = 0.049$).

Patient Function

Functional outcome was assessed in a subset a centers and patients (**Table 8**). WOMAC-determined pain and function scores plateaued by 3 months. Nonsignificant differences in scores were identified at follow-up visits of 3, 6, 12, 24, and 36 months after the index procedure (**Table 9**). Regression analysis suggested a strong

Table 1
Patient demographics (*n* = 1,152 patients)

Characteristic		(%)
Sex	Male	47.5%
	Female	52.5%
Age at surgery	Mean (SD)	65.26 (12.196)
Ethnicity	Caucasian	91.2%
	Asian	1.4%
	Hispanic	3.2%
	African-American	3.2%
	Other	0.9%
Occupation	Employed	32.9%
	Unemployed	0.7%
	Disability	1.9%
	Retired	45.8%
	Student	0.1%
	Unknown	18.6%
Height (inches)	Mean (SD)	67 (4)
Weight (pounds)	Mean (SD)	181 (42)
BMI	Mean (SD)	28 (5)
Comorbidities	Cardiovascular	589 (51.1%)
	Respiratory	115 (10.0%)
	Psychiatric	133 (11.5%)
	Neurologic	79 (6.9%)
	Genitourinary	103 (8.9%)
	Gastrointestinal	136 (11.8%)
	Musculoskeletal	401 (34.8%)
	Previous lower-extremity surgery	265 (23.3%)
ASA classification	Class I	7.0%
	Class II	73.4%
	Class III	18.5%
	Class IV	1.1%
	Class V	0%
	Class VI	0%

association between the need for revision surgery and surgeon (center effect) (*P*<0.001).

DISCUSSION

Summary of Principle Findings

In the cohort of 1,152 patients treated with the anterior approach to THA, the investigators found: (*i*) an acceptable complication profile, (*ii*) an early return to function, and (*iii*) a decline in complications in surgeons with greater than 100 case experiences.

Table 2
Surgical data (*n* = 1,152 patients; *n* = 1,275 hips)

Characteristic		*n* (%)
Hip operated on	Left	482 (37.8%)
	Right	545 (42.7%)
	Bilateral	125 (9.8%)
Previous surgery on affected hip	87 (6.8%)	
Preoperative diagnosis	Osteoarthritis	93.0%
	Avascular necrosis	3.9%
	Rheumatoid arthritis	0.5%
	Post trauma	1.4%
	Other	1.1%

Strengths and Limitations

The current study has several strengths. Participating surgeons across nine hospital sites improved the generalizability (external validity) of

Table 3
Surgical technique

Characteristic	
Length of incision (centimeters) Mean (SD)	9.6 (2.2)
Operative duration (minutes) Mean (SD)	95.3 (34.9)
C-arm total time (seconds) Mean (SD)	30.0 (15.4)
Type of Anesthesia	
General	49.0%
Regional	36.0%
Spinal	13.4%
Epidural	1.6%
Estimated blood loss (cc) Mean (SD)	427.4 (293.2)
Acetabular inclination/abduction (degrees) Mean (SD)	42.1 (6.6)
Acetabular anteversion (degrees) Mean (SD)	19.2 (7.7)
Leg-length discrepancy (±) (millimeters) Mean (SD)	3.9 (3.5)

Table 4
Implants used

Characteristic		n (%)
Acetabulum		
Bone grafting		0.6%
Outer diameter (millimeters)	Mean (SD)	54 (4.0)
Acetabular liner	Neutral	85.2%
	20°	9.1%
	Offset	3.8%
	10°	1.4%
	Other	0.5%
Diameter of acetabular linear	26 mm	0.1%
	28 mm	40.7%
	30 mm	0.1%
	32 mm	50.9%
	36 mm	3.8%
	38 mm	3.5%
	40 mm	0.1%
	44 mm	0.2%
	46 mm	0.3%
	48 mm	0.4%
Type	Press-fit	99.8%
	Cemented	0.2%
Implant company and brand used	Zimmer	39.2%
	Smith & Nephew	21.1%
	PLUS	17.7%
	Stryker	8.3%
	DePuy	7.0%
	Encore	3.9%
	Wright-Medical	2.3%
	Biomet	0.5%
Bearing surface		
Type	Metal-on-crosslinked polyethylene	59.9%
	Ceramic-on-crosslinked polyethylene	17.5%
	Ceramic-on-ceramic	12.9%
	Metal-on-metal	4.8%
	Oxinium-on-crosslinked polyethylene	4.5%
	Ceramic-on-metal	0.4%
Implant company and brand used	Zimmer	51.8%
	Smith & Nephew	30.7%
	Stryker	10.9%
	DePuy	4.6%
	Wright-Medical	1.0%
	Biomet	0.6%
	PLUS	0.3%
	Encore	0.1%
Femur		
Femoral head size	26 mm	0.1%
	28 mm	39.8%
	32 mm	50.3%
	36 mm	4.0%
	38 mm	4.6%
	40 mm	0.2%
	44 mm	0.1%
	46 mm	0.3%
	48 mm	0.5%
	50 mm	0.1%
Implant size (millimeters)	Mean (SD)	5.47 (3.355)
Neck Angle (degrees)	Mean (SD)	128.75 (3.395)
Type	Press-fit	94.6%
	Cemented	5.4%
	Zimmer	41.5%
	PLUS	18.0%
	Stryker	13.1%
	DePuy	8.5%
	Smith & Nephew	8.3%
	Encore	3.4%
	Biomet	4.2%
	Wright-Medical	2.7%
	Centrepulse	0.3%

the findings. The sample size of over 1,000 patients provided sufficient precision for data analysis. Careful attention to data management and independent data analysis from the operating surgeons further improved the validity of the findings. Although attempts were made to improve the quality of the reporting by site visits, when necessary, the findings are limited by the retrospective design. Inconsistencies in reporting also limited assessment of functional scores. Moreover, because of insufficient data, the investigators were unable to evaluate function in the early postoperative period (less than 3 months). Thus, the findings about return to function, while interesting for hypothesis-generation, require further confirmation in prospective studies. In addition, it is not known if some surgeons were selecting patients for the anterior approach.

Relevant Literature

Minimally invasive hip surgery has gained popularity, with several reported techniques including single- and double-incision approaches. Commonly reported single-incision techniques include the anterior approach, the mini-Watson-Jones approach, the trochanteric flake technique, miniposterior and mini-posterolateral approach. Dual-incision approaches

Table 5
Outcome data (discharge and assistive device information)

Characteristic		n (%)
Length of hospital stay	Mean (SD)	3.6 (2.4)
Discharge disposition	Home	82.6%
	Aging and long-term care/skilled nursing facility	8.8%
	Rehabilitation facility	8.5%
	Other	0.1%
Assistive device at discharge	Walker	51.8%
	Crutches	28.4%
	Cane	10.9%
	Assistive device indicated, but not specified	5.7%
	None	2.1%
	One crutch	0.8%
	Wheelchair	0.2%
Time to discard assistive device (days)	Mean (SD)	20.8 (13.7)

incorporate two mini-incisions (one anterior-based and one posterior-based).[2–9]

The miniposterior approach has been the focus of several uncontrolled case series;[16–18] however, little evidence exists to support the use of a muscle-splitting miniposterior incision over a standard posterior incision. Two randomized trials (Level 1 evidence, therapy) suggest no benefit to the miniposterior incision. A randomized trial of 219 patients treated with a standard posterior incision versus a miniposterior incision found no advantage to the smaller incision in hospital stay or short-term outcomes.[2] Another randomized trial of 135 patients reported similar results. There was no evidence that the mini-incision technique resulted in less bleeding or less trauma to the soft tissues of the hip, factors that would have produced a quicker recovery and a shorter hospital stay, than did the standard technique.[3] By virtue of requiring a posterior incision, the two-incision approach[4,5] also suffers the same limitations of a lack of observable benefit over conventional incisions.

Table 6
Outcome data (revision surgeries) (*n* = 1,277 hips)

Characteristic	n (%)
Primary revision surgery required[a]	35 (2.7%)
Aseptic loosening	17 (1.3%)
Periprosthetic fracture	9 (0.7%)
Hip dislocation[b]	8 (0.6%)
Infection	3 (0.2%)
Leg-length discrepancy	3 (0.2%)
Secondary revision surgery required[a]	0

[a] Patient may require revision surgery for multiple reasons, so these numbers do not add.
[b] Of eight dislocations treated in the operating room, three (0.2%) required implant revision (one liner, one femoral head, and one stem); five were treated with closed reduction in operating room.

Reports of the minianterolateral approaches to THA are also conflicting. No randomized trials have evaluated these approaches, but comparative observational studies do exist. In a cohort of 212 patients, the mini-incision was associated with less blood loss and shorter operating time; however, postoperative blood loss and complications did not differ between groups.[19] In another study, patients with THA via a mini-incision lateral approach had significantly earlier ambulation, less transfer assistance, and more favorable discharge dispositions; they also had decreased transfusion requirements and better functional recovery with early physical therapy.[6] Other investigators have shown that THA can be performed safely through a minimal incision anterolateral approach. Early results have demonstrated an increase in the length of operation compared with a standard approach, despite selection of smaller patients, but the authors expect this result will change with further experience. No benefit has been found with respect to perioperative blood loss, but the authors' results do suggest that for patients without additional medical problems, this technique may lead to a reduction in the length of hospital stay.[7]

Minimally invasive is often equated with "small incisions." However, the length of the incision was not reported to affect outcomes (function, pain, hospital stay) in a cohort of 60 patients treated with a mini- versus standard lateral incision for THA.[8]

The Anterior Surgical Approach to THA

In contrast to the other approaches about the hip, the anterior approach is an intermuscular approach that avoids detachment of muscle from bone. The biologic rationale for a single-incision anterior approach with preservation of muscle

Table 7
Outcome data (complications)

Characteristic	n (%)
Intraoperative complications	
Greater trochanter	12
Femoral head migration	1
Perforation	2
Calcar split	10
Femur fracture	11
Excessive bleeding	1
Acetabular #	1
Posterior Column Pelvic #	1
Postoperative complications	
Cardiovascular	
Congestive heart failure	1
Stroke	1
Atrial fibrillation	1
Myocardial infarction	1
Mild hypertension	1
Postoperative tachycardia	1
Pulmonary embolism	3
Peroneal clot	1
DVT	10
Psychological	
Delerium	2
Transient confusion	1
Neurological	
Anterolateral thigh parasthesia	1
Lateral femoral cutaneous nerve palsy	7
Lateral thigh numbness	5
Musculoskeletal	
Acetabular #	4
Pelvic #	2
Strain of tensor fasica lata muscle; partial tear	1
Marked pain	9
Soft tissue strain	1
Heterotopic bone formation	7
Hip abductor weakness/ quadriceps atrophy	3
Hip bursitis	1
Spinal stenosis	1
Leg-length discrepancy	9
Femur fracture conservative management	1
Nondisplaced fracture greater trochanter	1
Wound complications	
Wound hematoma	5
Infection	10
Rash around incision	1
Stitch abscess	8
Subcutaneous hemorrhaging from a drain site	3
Genitourinary	
Urinary Retention	1
Prostate problems	1
Urinary tract infection	1
Upper gastrointestinal bleed	2
Lower gastrointestinal bleed	1
Miscellaneous	
Hypokalemia	1
Postoperative anemia	16
Medication sensitivity	2
Seroma	6
Fever	2
Severe nausea	1
Edema	8
Death	1

Patients may have had multiple complications.

insertions is strong in comparison to posterior-muscle splitting or lateral-abductor splitting approaches. While the goal is to preserve all tendon attachments, one or more of the posterior rotator tendons may require partial release to facilitate femoral canal preparation. The authors' experience suggests that the obturator internus is most often released followed by the piriformis.

Proponents of the approach do not advocate small incisions for the approach, as the focus remains on sparing tissues rather than small incisions. The authors' single-incision anterior approach using intermuscular planes allows a surgical approach to the hip and implantation of a total prosthesis with no muscle, tendon, or trochanteric section, even partially. The single-incision approach allows for adequate positioning of the two prosthetic components, and preserving the muscular potential may further contribute to dynamic stabilization of the hip.

The anterior intermuscular approach has been the subject of two large observational cohort studies.[10–13] Siguier and colleagues[10] treated 1,037 patients with the anterior approach to THA between June 1993 and June 2000. The dislocation rate was 0.96% (10 of 1,037 hips). In another study, Keggi and colleagues reported their series of 2,132 primary THAs performed via the anterior approach.[11] Keggi's study reported a dislocation rate of 1.3% and excellent early patient function.

Table 8
Functional outcome

		Follow-up Time Points				
WOMAC	**Preoperative**	**3-Months Postoperative**	**6-Months Postoperative**	**1-Year Postoperative**	**2-Years Postoperative**	**3-Years Postoperative**
WOMAC Pain score	n = 307 75.11 (19.820)	n = 32 96.62 (3.114)	n = 206 90.44 (12.177)	n = 239 91.31 (12.989)	n = 89 93.07 (8.354)	n = 16 93.31 (1.926)
WOMAC Function score	n = 306 45.27 (12.112)	n = 32 88.14 (9.888)	n = 205 83.40 (15.268)	n = 236 83.43 (14.737)	n = 88 82.02 (13.406)	n = 16 77.33 (6.477)

Whether the results of this muscle-sparing approach can be extrapolated to surgeons with less experience remains unknown.

Matta and colleagues[14] described a single surgeon series of 437 consecutive, unselected patients who had 494 primary THA surgeries done through an anterior approach on an orthopedic table from September 1996 to September 2004. Three patients sustained dislocations for an overall dislocation rate of 0.6%, and no patients required revision surgery for recurrent dislocation. There were 17 operative complications, including one deep infection, three wound infections, one transient femoral nerve palsy, three greater trochanter fractures, two femoral shaft fractures, four calcar fractures, and three ankle fractures.

Across participating surgeons in the authors' study, a dislocation rate of 0.6% (8 dislocations) was found, and 0.2% (3 dislocations) required implant revision. Analysis across surgeons did not reveal clustering of dislocations in any particular center. The current series did not identify any ankle fractures and may reflect improved learning curve in the technique.

Another important finding of the authors' study is the early return to function, which reached plateau levels by 3 months. The study was limited by few centers collecting this data and using 3 months as the first evaluation point. It remains plausible that even earlier functional gains are realized with this approach. Future studies need to evaluate function at earlier time points throughout the first year. The findings at 1 year were consistent with functional gains (WOMAC scores) reported for standard THA.[20] Knutsson and Engberg[21] evaluated quality of life (sickness-impact profile) following conventional THA. They identified significant differences in patients' total, physical, and psychosocial quality of life 6 months postoperatively compared with preoperative status, but not between the preoperative status and 6 weeks after the total hip replacement surgery.

The authors' data suggests that surgeons with greater than 100 hip cases reduce overall complication rates. While this requires confirmation in other studies evaluating this approach, these findings are not inconsistent with learning curves reported for conventional THA.[22–25] In a cohort of 57,488 Medicare beneficiaries, Katz and colleagues[23] identified a significant decrease in complications in high-volume surgeons (>100 THAs) compared with low-volume surgeons (<50 THAs).

Need for Further Research

The anterior approach is gaining popularity, largely based upon anecdotal surgeon experiences with

Table 9
Surgical experience and outcomes (learning curve)

Center	*n*	Number of Years of Anterior Approach Practice	Number of Complications	Number of Revision Surgeries
1	110	2	8 (7.3%)	5 (4.5%)
2	35	7	5 (14.3%)	3 (8.6%)
3	313	4	21 (6.7%)	5 (1.6%)
4	73	2	20 (27.4%)	2 (2.7%)
5	221	2	14 (6.3%)	1 (0.4%)
6	198	3	38 (19.2%)	11 (5.5%)
7	52	5	9 (17.3%)	3 (5.7%)
8	84	2	19 (22.6%)	0

the technique. Marketing has further led to patientled promotion of tissue-sparing and other less-invasive approaches to arthroplasty. Evidence-based medicine posits that health care decisions should not be based upon opinion but rather the best available research. The authors' study demonstrates that the anterior approach to THA can be performed safely by surgeons with varying experience in the approach and technique. Additional studies are required to further delineate the learning curve, factors associated with prognosis following this approach, and return-to-function in comparison with alternative surgical approaches to THA.

SUMMARY

The anterior approach THA with an orthopedic table is a safe approach, with results generalizable to surgeons with varying surgical experience. Longer term follow-up and comparative studies are needed before widespread endorsement of this surgical approach to THA.

APPENDIX 1: ATHAC INVESTIGATORS

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APPENDIX 2: INTERVENTION (ANTERIOR TECHNIQUE FOR THA)

After administration of general or regional anesthesia, the patient is placed in the supine position on the ProFX table. A perineal post is used and the feet placed in the traction boots. It is normal to use a leg support for the leg that will not be operated on and no leg support for the hip that will be operated on. The hip that will not be operated on is placed in neutral rotation, extension, and abduction-adduction to serve as a radiographic reference for the operated side. The jack that will raise and lower the femoral hook is placed near the side of the patient so that the hook bracket will lie roughly parallel to the long axis of the patient. Avoiding external rotation of the hip to be operated on will make the external landmarks of the hip more reliable and enhance the landmark of the natural bulge of the tensor fascia lata muscle. The table should be leveled with the table-level button on the hand control. It is normal for the patient's arms to be placed roughly perpendicular outward and not over the chest.

The normal team consists of the surgeon, his assistant, the anesthesiologist, the scrub nurse, circulating nurse/table operator, and the X-ray technician. The following description refers to actions that may be taken by the surgeon, his assistant, or the operator of the ProFX table.

Though the incision is normally small (8 cm to 12 cm), drape a relatively wide area from just proximal to the iliac crest to the junction of the middle and distal thirds of the thigh. Draping a relatively wide area around the incision enhances the sterility by making the vinyl skin covering less likely to detach and thereby allowing mobility of the drape edges. In addition, the wider draping allows additional extensile access, if necessary.

The normal incision starts 2-cm posterior and slightly distal to the anterior superior iliac spine. This straight incision extends in a distal and slightly posterior direction to a point 2-cm to 3-cm anterior to the greater trochanter. On thinner patients, the bulge of the tensor fascia lata muscle marks the center of the line of the incision. After incision of the skin and subcutaneous, the tensor can be seen through the translucent fascia lata. Incise the fascial lata over the tensor and continue the fascial incission slightly distal and proximal to the ends of the skin incision.

Lift the fascia lata off the medial portion of the tensor and follow the interval medial to the tensor in a posterior and proximal direction. Dissection by feel is most efficient at this point and the lateral hip capsule can be easily palpated. Place a cobra retractor along the lateral hip capsule and retract the sartorius and rectus femorus muscles medially with a Hibbs retactor. It is easy to make the mistake of perforating and incompletely retracting the gluteus minimus muscle with the cobra, so check for this. If the retractors are properly placed the reflected head of the rectus that follows the lateral acetabular rim will be visible. A small periosteal elevator placed just distal to the reflected head and directed medial and distal elevates the iliopsoas and rectus femorus muscles from the anterior capsule. The elevator opens the path for a second cobra retractor placed on the medial hip capsule.

The medial and lateral retraction of the cobras brings the lateral femoral circumflex vessels into view as they cross the distal portion of the wound. These vessels are clamped, cauterized, and transected. Further distal splitting of the aponeurosis that overlies the anterior capsule and at times excision of a fat pad enhances exposure of the capsule and the origin of the vastus lateralis muscle. A trapezoidal section of the anterior capsule (wider laterally and narrower medially) is now excised, followed by placing the tips of the cobra retractors inside the medial and lateral capsule. A release of the lateral capsule parallel to the lateral acetabular rim will facilitate dislocation. In addition, excise the capsule at the base of the antero-lateral neck to expose the anterior junction of the neck and greater trochanter. This base of the neck exposure is facilitated by a Hibbs retractor that retracts the vastus and distal tensor.

A narrow Hohman retractor is now placed on the antero-lateral acetabular rim. With this exposure the antero-lateral labrum is excised and sometimes an associated osteophyte. Distal traction on the extremity will create a small gap between the femoral head and the roof of the acetabulum. A femoral head skid is placed into this gap and rotated to a supero-medial position. The traction is released. As the extremity and hip are externally rotated and leverage applied to the skid, the hip is dislocated anteriorly and the femur externally rotated 90°. If the hip is unusually difficult to dislocate, check for adequate capsular release and osteophyte excision and extend the hip slightly. After dislocation, place the tip of a narrow Hohman retractor distal to the lesser trochanter and beneath the vastus lateralis origin. Transect the capsule on the medial neck parallel to the neck and expose the lesser trochanter and posterior neck. During exposure of the posterior and medial neck, keep in mind that Hohman retraction of the vastus protects the innervation of this muscle, which comes from medial and at a surprisingly proximal location. Happily however, this muscle is typically also enervated more distally. Reapply traction, internally rotate, and reduce the hip.

Replace the cobra retractors around the medial and lateral neck and retract the vastus origin and distal tensor with a Hibbs. Cut the femoral neck with a reciprocating saw at the desired level and angle. Use the junction of the lateral shoulder of the neck and greater trochanter as the indicator for the level of the cut and place the lateral portion of the cut slightly distal to this point. Cut the medial portion of the neck first and take care to not cut the greater trochanter with the saw. The neck cut is completed with an osteotome placed in the sagital plane that divides the lateral neck from the medial greater trochanter. The level of the neck cut is a little more difficult to judge than from posterior. The author (MB) has experimented with cutting guides but now simply "eyeballs" the cut. Drill a 4.5-mm diameter hole into the anterior head and then insert the femoral head corkscrew. Extract the head.

The original technique of Robert Judet (still used by Theirry Judet) is to cut the neck with the hip dislocated. The level of the cut is, in this case, judged by the level of the lesser trochanter. This technique introduces some danger of continuing the cut into the greater trochanter. The cut is completed by an osteotome to the supero-lateral neck.

Begin the anterior THA by cutting the neck in situ and then extracting the head. The advantage to this technique is that it avoids the dislocation step. The disadvantage is that the head is more difficult to extract and at times the head must be sectioned to remove it. The dislocation step increases the rotational mobility of the femur and thereby enhances femoral exposure for broaching and prosthesis insertion.

Throughout the procedure the surgeon will find that the tensor fascia lata muscle is potentially vulnerable to injury. Take care not to lever too hard on this muscle with retractors. During cutting of the neck, the relatively dull side of the oscillating saw blade will cut the muscle if it contacts it. Levering the femoral head skid through wide angles can also lacerate the muscle. As the cut femoral neck is extracted, the sharp bony edge can also lacerate the muscle, so use a Rongeur to round the neck cut or at least take care to protect the muscle with the Hibbs during extraction. Attention to this muscle needs to continue during the acetabular reaming and insertion and femoral broaching phases. If an initial injury to the muscle fibers is avoided, the muscle seems to hold up well through the procedure. On the other hand, an early laceration to the surface of the tensor seems to hurt its capability to resist further damage. The ProFX table, however, makes preservation of the soft tissues easier by its external and internal control of the femur, and thereby makes leverage against the soft tissues less necessary.

The acetabulum is now visualized and prepared. External rotation of the femur of about 30° usually facilitates acetabular exposure. A trochanteric retractor is preferred over the anterior rim of the acetabulum to retract the anterior muscles. Take care to place the tip of this retractor on bone and not into the anterior soft tissues. A posterior retractor is placed with the tip initially on the postero-superior rim and subsequently on the mid-posterior rim. Excise the labrum circumferentially. Excise part of the posterior capsule that bulges over the posterior rim. Excision of the most prominent band of inferior capsule will facilitate later placement of the acetabular liner. Begin reaming under direct vision and later check with the image intensifier to confirm depth of reaming and adequate circumference. The indicators of torque and acetabular appearance are also used.

Insert the acetabular prosthesis with a normal straight inserter. The author (MB) uses the image intensifier to watch the position and progressive seating of the prosthesis. Angulate the image 5° away from the midline and 5° cephalad to simulate the direction of the X-ray beam on a postoperative AP pelvis. Before using image control, confirm that the pelvis is level with a midline image view. Symmetry of the obturator foramina or centering of the coxyx to the symphysis confirms a level pelvis. If the pelvis is not level, the table can be tilted to compensate as needed. The liner is inserted in the normal fashion and prior excision of labrum and prominent posterior and inferior capsule will facilitate this. To shorten the distal portion of the incision, it is possible to use angulated reamers and angulated acetabular insertion devices.

The use of the image intensifier during the procedure will vary according to the surgeon's preference. It was not used by Robert Judet and is not currently used by Theirry Judet. To use it for reaming is probably most controversial. It is advocated for acetabular positioning and also to check leg length with the femoral trials. However, the procedure can be done completely without it while relying on the traditional methods of preoperative planning, guides, relation to bony or Steinman pin landmarks, as well as soft-tissue tension. Maintenance of a 1-m distance from the image makes personnel X-ray exposure unmeasurable by radiation badges.

Following acetabular insertion, the gross traction control on the table is released and the femur internally rotated to neutral. The vastus ridge is palpated and the femoral hook placed just distal to this and around the posterior femur. The hook is attached to the most convenient hole on the bracket. The femur is now externally rotated 90° and the hip hyperextended and adducted. This position is achieved by rotating the wheel at the end of the leg spar, dropping the leg spar to the floor, and adducting it. Remember to release the gross traction lock to prevent a hyperextension stretch to the femoral nerve.

For proximal femoral exposure, the author (MB) use a long-handled cobra with the tip on the posterior femoral neck (now facing medially) and place the tip of the trochanteric retractor posterior to the tip of the trochanter. It is now necessary to visualize the medial aspect of the greater trochanter and obtain some femoral mobility that allows the femur to come slightly lateral and anterior. The proximal femur is now raised by the femoral hook until the tissues come under moderate tension. It is important to feel the tension by manually lifting the hook up and down as the hook is raised. You should be able to manually lift the femur higher than the level the hook has raised it to. Too much tension can cause a fracture of the greater trochanter. Following this initial maneuver, the posterior ridge of the greater trochanter usually lies posterior to the posterior rim of the acetabulum. The femur needs to be mobile enough so that lateral and anterior displacement brings the posterior edge of the trochanter lateral and anterior to the posterior rim of the acetabulum. A band of postero-superior capsule will be seen to tether the femur at its attachment to the sulcus between the lateral neck remnant and the medial trochanter. Excise this attachment and replace the trochanteric retractor closer to the tip of the trochanter so that it retracts the gluteus minimus and medius, and possibly also the piriformis and obturator internus tendons. The obturator externus tendon insertion will be found at the point normally termed the "piriformis fossa." The piriformis and obturator internus tendons insert on the mid portion of the tip of the greater trochanter. Manually check the mobility of the femur by pulling on the hook and if it is mobile enough, raise the jack to support the femur in the desired position. Depending on the requirements for femoral mobility, the surgeon may choose to release one or more of the short external rotator tendons.

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