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Original Research

The Anterior-Based Muscle-Sparing Approach for Conversion Total Hip Arthroplasty is Safe and Effective

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Background: Total hip arthroplasty (THA) after prior hip or acetabular fracture fixation is considered higher risk than primary THA, as studies have shown reduced implant survival and higher infection rates. The anterior-based muscle-sparing (ABMS) approach can potentially reduce some of these risks by utilizing a new surgical interval. The goal of this study is to analyze the efficacy of the ABMS approach for conversion to hip arthroplasty surgery after previous fracture fixation with comparison to posterior approach.
Methods: This retrospective cohort study included patients with prior hip surgical intervention requiring hardware then converted to a THA using the ABMS or posterior approach at 1 institution between 2013 and 2020. Outcomes studied included postoperative complications, 30-day emergency department visits, 90-day readmission rates, any reoperation and patient-reported outcome measures.
Results: A total of 85 patients (51 male and 34 female) in the ABMS group and 17 patients (9 male and 8 female) in the posterior group were included. Within the ABMS group, the mean age was 65.6 years (±16.2) with a mean body mass index of 27.5 kg/m^2 (±5.4). The average operative time was 85 minutes (±35) and estimated blood loss was 178 mL (±183). There was 1 postoperative complication (dislocation) within 90 days, 1 patient made an emergency department visit within 30 days, and there were 3 readmissions within 90 days; only 1 readmission was orthopaedic in nature. One patient required reoperation (1.2%) over the study period of 5.0 years (±2.1). Patient-reported outcome measures indicate successful return of function. Operative, hospital, and outcome data were similar between patients receiving the ABMS and posterior approach.
Conclusions: This study is the first to evaluate outcomes of conversion THA using the ABMS approach, when compared to the posterior approach. Our institution's experience demonstrates that the ABMS approach is safe and effective for conversion THA after prior fracture fixation.

Introduction

Conversion total hip arthroplasty (cTHA) is a well-studied procedure with a projected increase in demand as individuals live longer and undergo surgical treatment for stabilization of hip fractures that may fail and require conversion to total hip arthroplasty (THA). The majority of cTHAs occur after prior hip or acetabular fracture fixation, due to non or malunion, osteonecrosis, or post-traumatic arthritis [1-3]. cTHA is also performed in cases where prior surgical management for conditions such as Legg-Calvés-Perthes disease, slipped capital femoral epiphysis (SCFE), or developmental dysplasia of the hip has been performed [4]. Despite its benefits, cTHA is associated with significantly poorer outcomes when compared to primary THA, including increased blood loss, longer hospital length of stay, and increased postoperative complications such as readmissions, revisions, dislocations, and prosthetic joint infections [5-7]. This higher complication burden

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and poorer outcomes can be attributed to the unique technical challenges of cTHA [5-7].

Previous studies surrounding surgical approaches to cTHA have primarily been performed using the posterior, lateral, or direct anterior (DA) approaches [8,9]. Anatomically, these represent distinct entities with unique inherent risks and benefits. Posterior approaches to the hip (Kocher-Langenbeck, Moore, Gibson) split the gluteus maximus muscle bluntly and sacrifice the short external rotators (the gemellus superior, obturator internus, and gemellus inferior muscles) [10]. A primary advantage of the posterior approach is its excellent acetabular exposure, which can be important for the removal of hardware (ROH) often necessary in cTHA cases, yet a main drawback of this approach is a comparatively higher risk for posterior dislocation [11]. Direct lateral approaches split the gluteus medius muscle fibers [12] or else decorticate the gluteus medius bone insertion [13]. This lateral approach has a relatively lower rate of dislocation, but can be associated with lateral hip pain and postoperative Trendelenburg sign [14]. The direct anterior approach (DAA; Smith-Petersen) is a muscle-sparing approach between the tensor fasciae latae and sartorius muscles that is notable for a low dislocation rate, but is associated with increased risk of intraoperative and postoperative complications partially attributed to its steep learning curve [15]. These factors have likely impacted surgeon adoption, especially in the setting of the unique challenges posed by cTHA. Research on the use of the anterolateral approaches (Watson-Jones, Rottinger) for cTHA remains understudied, with 1 study by Ostojić et al. suggesting it may be associated with faster recovery than cTHA performed through the posterior approach [16]. These approaches utilize the interval between the tensor fasciae latae and gluteus medius, with part of the gluteus medius detached originally. The anterior-based muscle-sparing (ABMS) approach, also known as a modified Watson-Jones or Rottinger approach, is a newer muscle-sparing variation that preserves the gluteus medius muscle and which has demonstrated excellent results in primary THA ([17-19]). One of the advantages of the ABMS approach is the ability to extend the incision distally without crossing any intervals, as opposed to the DAA, which can facilitate straightforward access to the lateral femur for ROH that can be important for cTHA. The goals of our study are to determine if the ABMS approach is a safe and effective approach for cTHA. The study of optimal surgical approach for cTHA remains challenging, as there exist no prospective randomized control trials (RCTs) to address this matter. By reporting on outcomes of the ABMS approach for cTHA, we hope to add to the growing body of knowledge of approaches available to care for patients with challenging conversion cases.

Material and methods

Approach: ABMS or posterior

One of the advantages of the ABMS approach, which utilizes the interval between the tensor fasciae latae posteriorly and the gluteus medius muscle anteriorly, is the ability to extend the incision distally without crossing any intervals. The ABMS approach is performed with the patient in the lateral decubitus position, which allows a patient's pannus to fall out of the surgical plane when operating on patients with obese body habitus and can facilitate straightforward ROH. The surgeon is able to extend the incision distally by splitting the iliotibial fascia then reflecting the vastus lateralis anteriorly to access the lateral proximal femur. This is done through the index procedure and does not require a second incision. Excellent exposure is realized allowing the surgeon to remove hardware, either a sliding hip screw or screws from a prior closed reduction and percutaneous pinning (CRPP). For the group of patients receiving surgery through the ABMS approach, all cases of hardware removal were performed with a single incision utilizing this technique. All other patients received surgery through the posterior approach.

Data collection

Institutional review board approval was obtained; this study was classified as exempt. The electronic medical record (EMR) database EPIC (EPIC Systems Corporation Verona, WI) was used to identify patients and pull data based on inclusion criteria. Patients were identified based on the Current Procedural Terminology code for a conversion of previous hip surgery to a THA. Included in this study were any individuals who underwent cTHA performed by 1 of 3 fellowship-trained arthroplasty surgeons within our practice using the ABMS or posterior approach between October 1, 2016, and October 1, 2023.

Patients with hardware surgically placed before their conversion surgery were included; this included patients with hardware in place from a prior surgery at the time of their conversion surgery, as well as hardware that was previously inserted and removed in a different procedure before conversion surgery. Patients were included that had undergone the following procedures before their conversion surgery: CRPP, acetabular fracture fixation, dynamic hip compression screw (DHS), intramedullary nailing (IMN), and SCFE. Exclusion criteria included any patient undergoing surgical intervention that did not involve hardware placement, including arthroscopy and irrigation and debridement procedures, or who underwent a cTHA procedure using the direct anterior approach (Fig. 1). Based on our criteria, our EMR database identified 85 patients who underwent cTHA using the ABMS approach and 17 patients who underwent cTHA using the posterior approach for inclusion.

Demographic, operative, and hospital outcome data were obtained from the institutional EMR, including sex (male or female, as recorded in the EMR), age, body mass index (BMI; classified underweight <18.5, healthy weight 18.5-24.9, overweight 25-29.9, or obese >30), and American Society of Anesthesiologists (ASA) score. Preoperative and perioperative data collected included preoperative diagnosis, anesthesia type and duration, procedure duration (calculated from incision start to incision close), intraoperative estimated blood loss (EBL) (mL), and requirement for blood transfusion within 7 days. Postoperative data gathered included length of hospital stay (calculated in days from hospital admission time to hospital discharge time), discharge disposition, 30-day emergency department (ED) visits, and 90-day unplanned hospital readmissions. Postoperative complications were obtained via the EMR from a report built by an internal analyst using the Centers for Medicare and Medicaid Services codes and definition that identified both index admission complications and postdischarge complications. Based off this definition, if a patient had the same complication twice, it was only accounted for once. All patients included in this study had a manual chart review for added evaluation of hospital course and postoperative outcomes, capturing any occurrences of reoperation occurring after cTHA index surgery on or before October 1, 2023. For deceased patients, death date was recorded as the final endpoint. Implant survival and reoperation rate were calculated with this data.

Patient-reported outcome measures (PROMs) included preoperative, 1-year, and final follow-up (August 12, 2024). Visual analog scale pain, Hip Disability and Osteoarthritis Outcome Score Joint Replacement and University of California, Los Angeles scores were

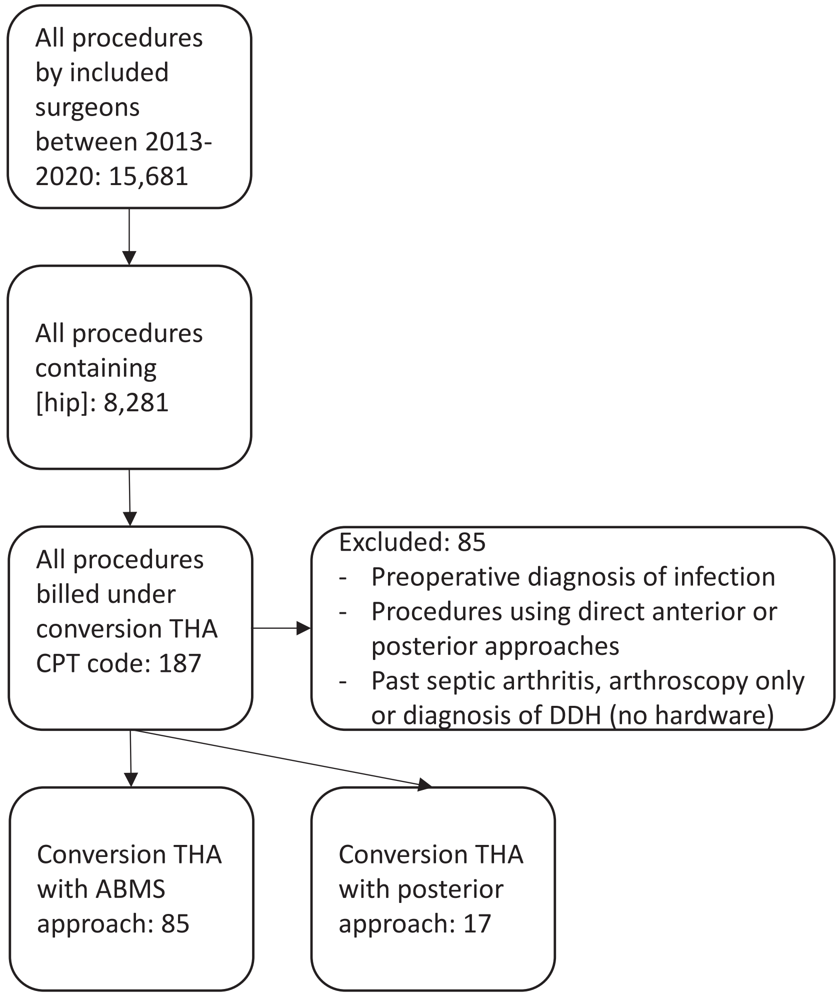

Figure 1. Study inclusion or exclusion criteria flowchart for conversion THA cohort. CPT, Current Procedural Terminology; DDH, developmental dysplasia of the hip.

collected from an in-house database. Satisfaction scores evaluating pain relief, functional improvement, procedure meeting expectations, and surgeon were collected for postoperative time points at 1 year and at the final follow-up on August 12, 2024.

Data analyses

Descriptive statistics were analyzed using Microsoft Excel 2013 (Microsoft Inc., Seattle, WA) software. A power analysis was conducted to determine the adequacy of the sample size for detecting true differences in revision rates between the ABMS and posterior groups. The analysis was based on a 2-sided confidence interval of 95%. The power, based on normal approximation with continuity correction, was calculated to be 16.9%, indicating a low likelihood of detecting a true difference between the groups. To meet the standard power of 80%, a much larger sample size (about 1500 patients per approach group) would be required. Despite the low power, the study proceeded because the sample size for the posterior group could not be increased. This limitation was due to the fact that the surgeons in the cohort predominantly perform the ABMS approach for most primary and revision THAs. Consequently, the available sample size reflects the real-world practice patterns of these surgeons, making it essential to continue the study to provide insights into the outcomes associated with each cTHA approach, even with the inherent limitations.

Results

Demographics

There were 85 patients that underwent a cTHA with the ABMS approach: 34 (40%) women and 51 (60%) men. The average age was 65.6 years (±16.2). The average BMI at the time of surgery was 27.5 kg/m^2 (±5.4). The average ASA score was 1.6 (±1.2) (Table 1). Seventeen patients underwent cTHA with the posterior approach: 8

Table 1
Baseline characteristics of 102 conversion THA patients.

Characteristic	ABMS (N = 85)	Posterior (N = 17)
Age (y)	65.6 ± 16.2	63.7 ± 11.7
Sex[a]		
Female	34 (40 %)	8 (47%)
Male	51 (60 %)	9 (53%)
BMI	27.5 ± 5.4	29.9 ± 7.0
BMI Categories[a]		
Underweight (<18.5)	1 (1.2 %)	0 (0%)
Healthy weight (18.5-24.9)	33 (38.8 %)	3 (17.6%)
Overweight (25-29.9)	26 (30.6 %)	7 (41.2%)
Obese (>30)	25 (29.4 %)	7 (41.2%)
ASA classification	1.6 ± 1.2	3.0 ± 0.4

[a] N (% of total).

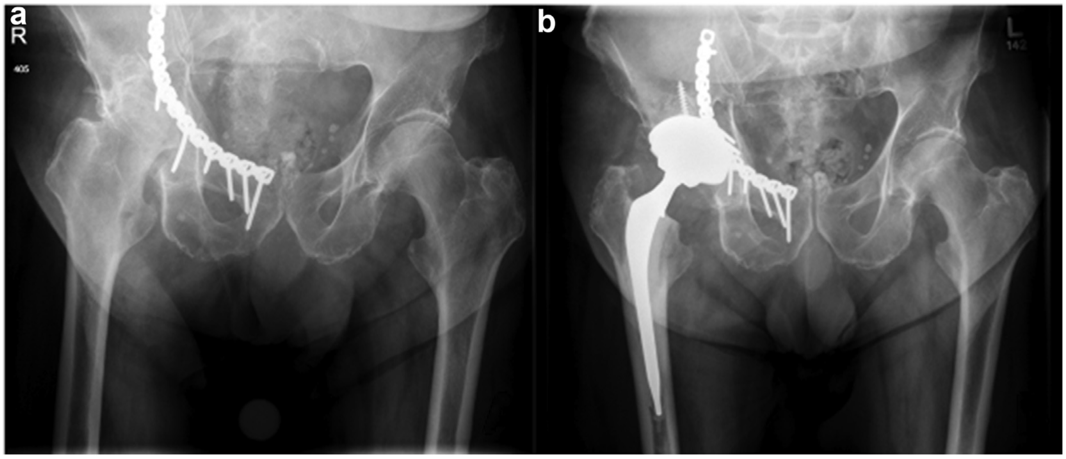

Figure 2. (a) AP radiograph demonstrating post-traumatic arthritis of the right hip following previous open reduction internal fixation for an acetabular fracture. (b) AP radiograph following conversion THA with the ABMS approach. AP, anteroposterior.

(47%) women and 9 (53%) men. The average age was 63.7 years (±11.7). The average BMI at the time of surgery was 29.9 kg/m^2 (±7.0). The average ASA score was 3.0 (±0.4) (Table 1).

Among the ABMS group, a total of 39 patients (46 %) had a preoperative diagnosis of CRPP. Three patients had previous ROH, while the remaining 36 had hardware in place at the time of conversion surgery. Acetabular fractures accounted for the preoperative diagnosis of 18 patients (21 %) (Fig. 2); 3 had previous ROH while the other 15 had hardware in place. There were 11 cases (13 %) of prior DHS fixation (Fig. 3), 4 of which had previous ROH and 7 of which had no prior ROH. Nine patients (11%) had a preoperative diagnosis of SCFE, 5 of whom had previous ROH while the remaining 4 had hardware in place. Eight patients (9%) had a prior IMN placed; half of these patients [4] underwent ROH while the rest had hardware in place (Table 2). Within the posterior group, most—7 (41%)—had a prior diagnosis of acetabular fracture, 1 (6%) had DHS, 2 (12%) had SCFE, 4 (24%) had IMN, and 3 (18%) had hemiarthroplasty. For all patients in the posterior group, hardware was in place at the time of cTHA.

Surgical and perioperative characteristics

For both the ABMS and posterior groups, 100% (n = 85; n = 17) of patients received general anesthesia and no patients received spinal anesthesia. Within the ABMS group, the anesthetic duration averaged 131 minutes (±37). The average length of surgery was 85 minutes (±35). The average length of stay was 2.2 days (±2.2). The EBL was 178 mL (±183). Three (3.5%) patients underwent transfusion within 7 days of surgery (Table 3). Among the posterior group, the anesthetic duration averaged 164 minutes (±44). The average length of surgery was 130 minutes (±59). The average length of stay was 2.9 days (±1.0). The EBL was 397 mL (±231). One (6%) patient underwent transfusion within 7 days of surgery (Table 3).

Postoperative data and complications

A single complication within 90 days was recorded within the study group, occurring in a patient who received the ABMS approach, which consisted of a dislocation, per Centers for Medicare and Medicaid Services definition of complication (Table 4). This patient, with a prior diagnosis of acetabular fracture, dislocated immediately postoperatively and was close reduced at that time. There were no instances of fracture, superficial infection, or deep infection within 90 days. Among the ABMS group, the rate of ED visits (within 30 days) was 4.5% (n = 4). One visit addressed inadequate pain control. The other 3 visits represented the 3 patients who required readmission within 90 days. The readmission

Figure 3. (a) AP radiograph demonstrating post-traumatic arthritis of the left hip following open reduction internal fixation of the left hip. (b) AP radiograph following conversion THA with the ABMS approach with ROH. AP, anteroposterior.

Table 2
Diagnosis based on previous surgery.

Characteristic	ABMS (N = 85)	Posterior (N = 17)
CRPP[a]	39 (46 %)	0 (0%)
Previous ROH	3	0
No previous ROH	36	0
Acetabular fracture[a]	18 (21 %)	7 (41%)
Previous ROH	3	0
No previous ROH	15	7
DHS[a]	11 (13 %)	1 (6%)
Previous ROH	4	0
No previous ROH	7	1
SCFE[a]	9 (11 %)	2 (12%)
Previous ROH	5	0
No previous ROH	4	2
IMN[a]	8 (9 %)	4 (24%)
Previous ROH	4	0
No previous ROH	4	4
Hemiarthroplasty to THA	0 (0%)	3 (18%)
Previous ROH	0	0, N/A
No previous ROH	0	3

[a] N (% of total).

indications for these patients included medical admissions for failure to thrive with urinary tract infection and an episode of weakness or vertigo determined after workup for acute coronary syndrome and pulmonary embolism to be a side effect of a newly prescribed medication. There was 1 orthopaedic readmission due to ground level fall involving fracture of the contralateral hip without damage to the cTHA side. All other patients underwent uncomplicated recovery. There were no ED visits (within 30 days) or readmissions (within 90 days) within the posterior group. Among the ABMS group, most patients were discharged home (52%, n = 44), or home with health services (26%, n = 22). Sixteen percent (n = 14) were discharged to a skilled nursing facility and 6% (n = 5) went to a rehabilitation facility. For the posterior group, 1 patient (6%) discharged home while most went home with health services (n = 10; 59%). One patient (6%) went to rehab and 5 (29%) went to a skilled nursing facility.

One patient, within the ABMS cohort required reoperation, occurring just over a year (1.1 years) following index conversion THA procedure for prior acetabular fracture (Table 4). It was the same patient who had a postoperative dislocation following index cTHA procedure who required reoperation. The patient underwent revision posterior acetabulum plating for loose acetabular component and broken acetabular hardware. For the past year and a half, the patient has done well, and has required no further intervention since.

Postoperative follow-up was calculated from date of surgery to date of final follow-up (August 12, 2024) or patient death, with an average of 5.0 years (±2.1) across the ABMS group and 3.4 years (±2.2) across the posterior group. For the ABMS group the reoperation rate was 1.2% and for the posterior group it was 0% over this period. There were 5 patient deaths, all were unrelated to cTHA procedure.

Table 3
Surgical and perioperative data.

Characteristic	ABMS (N = 85)	Posterior (N = 17)
Anesthesia type[a]		
General	85 (100 %)	17 (100%)
Spinal	0 (0 %)	0 (0%)
Anesthesia duration (mins)	131 ± 37	164 ± 44
Length of surgery (mins)	85 ± 35	130 ± 59
Length of stay (d)	2.2 ± 2.2	2.9 ± 1.0
EBL (mL)	178 ± 183	397 ± 231
Transfusion (within 7 d)[a]	3 (3.5 %)	1 (6%)

[a] N (% of total).

Table 4
Postoperative and complication data.

Characteristic	ABMS (N = 85)	Posterior (N = 17)
Discharge disposition[a]		
Home or self-care	44 (52 %)	1 (6%)
Home health services	22 (26 %)	10 (59%)
Rehab	5 (6 %)	1 (6%)
Skilled nursing facility	14 (16 %)	5 (29%)
Overall postoperative complications[a]	1 (1.2 %)	0 (0%)
Fracture (90 d)	0 (0 %)	0 (0%)
Dislocation (90 d)	1 (1.2 %)	0 (0%)
Deep infection (90 d)	0 (0 %)	0 (0%)
Superficial infection (90 d)	0 (0 %)	0 (0%)
30 day ED Visit[a]	4 (4.5 %)	0 (0%)
90-day Hospital Readmission[a]	3 (3.5 %)	0 (0%)
Average follow-up (y)	5.0 ± 2.1	3.4 ± 2.2
Patients requiring reoperation	1 (1.2 %)	0
Time from cTHA to reoperation (y)	1.1	NA
Indication	Revision posterior acetabulum plating for loose acetabular component and broken acetabular hardware just over a year after conversion THA.	NA

[a] N (% of total).

PROMs

PROMs among the ABMS group were compared to preoperative scores and evaluated at 1 year and final follow-up, August 12, 2024. Patients reported significantly improved and sustained functional status following cTHA using the ABMS approach (Table 5). Function and satisfaction scores remained consistently high over time, with an average last follow-up of 5.0 ± 2.1 years.

Discussion

It is well established that cTHA is associated with higher postoperative complication rates than primary THA due to previous postoperative trauma [20]. According to Newman et al., when compared to primary THA patients, cTHA patients typically have longer surgeries, higher blood loss, and require blood transfusions more often [21]. Additionally, factors such as retained hardware in a failed procedure, osteoporotic bone, and a more fragile elderly

Table 5
PROMs for ABMS group.

PROM	Preoperatively (N = 32)	At 1 year postoperatively (N = 30)	At final follow-up[a] (N = 20)
Function			
VAS Pain	6.5 ± 2.4	0.8 ± 1.0	1.5 ± 2.5
UCLA	3.7 ± 2.4	6.0 ± 2.2	6.3 ± 2.2
HOOS JR Interval Score	29.7 ± 16.7	94.3 ± 10.9	97.7 ± 8.5
Satisfaction			
Pain Relief	—	9.3 ± 1.5	9.2 ± 1.5
Functional Improvement	—	9.2 ± 1.5	9.3 ± 1.5
Procedure Met Expectations	—	9.5 ± 1.4	9.2 ± 1.9
Surgeon	—	9.8 ± 1.0	9.6 ± 1.1

VAS, visual analog scale; HOOS JR, Hip Disability and Osteoarthritis Outcome Score, Joint Replacement; UCLA, University of California, Los Angeles.
[a] Final follow-up averaged 5.0 ± 2.1 years.

patient population all contribute to the associated increase in complication rates observed [3].

Dislocation and other complications

The only complication recorded in our study groups was one instance of immediate postoperative dislocation, which occurred in a patient who received the ABMS approach with a prior diagnosis of acetabular fracture. Certain injuries, such as fractures and dislocations to the posterior acetabulum, involve disruption of the capsule and surrounding soft tissues that can be further damaged during reconstruction, with rates of dislocation up to 11% following cTHA noted for patients with these preoperative diagnoses [22]. Similar to recent work investigating the DAA in this population [23], we hypothesize that the risk of dislocation may be mitigated with the ABMS approach because the posterior capsular structures can remain intact. However, despite that it is well-established that the posterior approach offers an increased risk of dislocation compared to other surgical approaches, [24-26] there were no dislocations among the small group of posterior approach patients studied. A larger study is needed to further assess this hypothesis and investigate the dislocation risk profile of the ABMS approach when compared to posterior and DA approaches.

Infection is a major complication following conversion THA, and has been extensively studied, although not with the ABMS approach, which may offer other benefits based on technical factors such as ease of hardware removal and associated potential for shorter operative time [27]. Contributing factors underlying the increased infection risk observed in cTHA compared to primary THA may include longer operating times and greater blood loss, both outcomes related to scar tissue and the increased complexity of operating in an area of previous trauma and surgical fixation [23,28,29]. We found that average operating time was 85 minutes (±35) and EBL was 178 mL (±183), lower than what is reported in the literature for patients undergoing conversion THA [30]. Use of the ABMS approach for primary THA reports an average operating time of 65 minutes (±18) and EBL was 204.1 mL (±65.9) [19]. The moderate increase in operating time observed is likely accounted for by the additional complexity of the cTHA procedure and the frequent need for hardware removal compared to primary THA. The lower blood loss observed in this cohort of cTHA patients when compared to primary THA patients was unexpected; the extremely high standard of deviation associated with the blood loss in the cTHA cohort points to greater variability in blood loss. This may be due to the heterogeneity in this patient population with respect to prior surgeries, hardware status, and surgical complexity. Regardless, lower average operating time and blood loss likely lower infection risk. Operating time and blood loss were notably higher in the group receiving the posterior approach; average operating time was 130 minutes (±59) and EBL was 397 mL (±231). No incidences of postoperative infection were reported with either approach. Further work with larger sample size can help to assess infection risk related relative to approach in cTHA.

Gittings et al. reported an infection rate of 18% in a cTHA population; however, surgical approach was not studied [31]. Similarly, Douglas et al. reported an overall complication rate of 30.8% in a cohort of 8368 conversion patients (approach not cited), and 7.3% hospital readmission rate within 30 days [5]. Our rate of infection (0 %), complications (1.2%—one postoperative dislocation—for the ABMS approach and 0% for the posterior approach), and hospital readmissions within 90 days (3.5% for the ABMS approach and 0% for the posterior approach), are significantly lower than these studies. Only 1 of these readmissions was orthopaedic in nature (contralateral hip fracture following ground level fall), as the other 2 patients were admitted to medical teams related to pre-existing health conditions. We observed no instances of refracture within the 90-day period monitored. Together, these results demonstrate the ABMS approach to be a safe and effective surgical approach when compared to the posterior approach for cTHA.

Short-term follow-up

Many studies have found cTHA to be more similar in perioperative and postoperative outcomes to revision THA due to increased complexity [6,21,32-34]. cTHA is notable for inferior survival rates when compared to a THA performed for primary osteoarthritis, with survival characteristics related to preoperative injury [35]. Observing patients with previous acetabular fractures, Morison et al. found that the 10-year survivorship after THA was lower in these patients than in a matched cohort undergoing primary THA (70% vs 90%) [22]. In a cohort of patients undergoing conversion of hemiarthroplasty to THA, Sarpong et al. found a rate of rerevision at 2 years was 10.0% [36]. In our ABMS cohort of mixed preoperative diagnoses with an average follow-up of 5.0 years (±2.1), only 1 patient required reoperation for a revision rate of 1.2%, indicating excellent short- to mid-term viability (99%). Among our posterior cohort—which included 3 converted hemiarthroplasty patients—with a slightly shorter average follow-up of 3.4 years (±2.2), there were no instances of reoperation. Future work addressing long-term implant survivorship is needed, but initial results are reassuring that the ABMS approach does not appear to be associated with decreased implant longevity or increased need for reoperation.

PROMs

Similarly to implant survival, the literature on PROMs following cTHA demonstrates varied results and indicates the importance of preoperative diagnosis in postoperative function. Tamaki et al. found that patients undergoing cTHA for failed periacetabular osteotomy had significantly worse PROMs at 1 year compared to a matched primary THA cohort [37]. Alternatively, Vles et al., observing a cohort undergoing cTHA for failed interventions for proximal femur fractures, found equivalent PROMs when the cTHA group was compared to a matched primary THA cohort [34]. Analyzing a cohort of mixed preoperative diagnoses undergoing cTHA, Lipof et al. found no statistical difference in PROMs when compared to primary THA patients at a final follow-up of close to 2 years [38]. In our ABMS cohort of mixed preoperative diagnoses utilizing the ABMS approach, we report at 1 year and final follow-up (5.0 years ±2.1) PROMs indicating high function, high satisfaction, and low pain. While PROMs participation was limited (35 % at 1 year and 24% at the final follow-up), research supports non-responders experience similar PROMs as responders [39]. PROMs information was not available for the posterior approach cohort due to low completion rates within a small sample. Among the ABMS group, minimal clinically important difference was achieved in the Hip Disability and Osteoarthritis Outcome Score Joint Replacement score [40]. Results within this ABMS cTHA cohort are remarkably similar to PROMs in primary THA undertaken with the ABMS approach [19,41-43]. ABMS conversion THA patients in our study reached minimal clinically important difference ([44,45]) and a patient acceptable symptom state established for primary THA ([46]), indicating functional outcomes are both similar and successful with the ABMS approach.

The difficulty of comparing between surgical approaches

Patients included in this study were not randomized to the surgical approach they received; each patient who underwent cTHA with the ABMS or posterior approach was selected by the surgeon after reviewing the case history, physical exam, and imaging. Because of this lack of randomization, utility of including patients who received the posterior approach as a control group is inherently limited. Ultimately, the core tenets of a control group are that: 1) it is well-matched to the study group, 2) it is exposed to similar injury mechanisms, 3) it receives an appropriate comparator intervention, and 4) it is part of a study design that includes blinding and randomization to minimize bias and confounding. [47,48] Our posterior approach cTHA cohort is well-matched to the study group (patients were selected for inclusion in the study based on the same criteria, received care from the same practice, and were treated by the same surgeons) and likely exposed to similar mechanisms (based on a localized patient population with similar surgical history undergoing cTHA and included in this study based on the same inclusion criteria). Both groups received appropriate intervention in the form of cTHA. However, there was no blinding nor randomization in this process, and both bias and confounding are likely active and limit the utility of this comparison group for forming meaningful conclusions. To the best of our knowledge, no prospective RCT exists for evaluating approach in cTHA, and it is unlikely an RCT will be performed, as it is neither benevolent nor just to randomize patients to receive surgery by an approach that their surgeon feels is inappropriate. The choice of approach will likely continue to be based on patient characteristics, surgeon experience, and the specific clinical scenario, limiting conclusions on the feasibility of this approach for all cTHA procedures.

One of the primary limitations of this study is the small sample size. With 85 individuals in the ABMS group and 17 in the posterior group, the study is underpowered to detect type II errors. This means that the study may not have sufficient statistical power to identify a true difference in complications, 30-day ED visits, and 90-day readmissions between conversion THA using the ABMS approach and conversion THA using the posterior approach. Consequently, the hypothesis that there will be no significant difference between the 2 groups may not be adequately tested, and any conclusions drawn should be interpreted with caution. Our practice was an early adopter of the ABMS approach, [19] and preferentially utilizes this approach for most primary THA procedures as well as many revision surgeries. This is evident in the variation in number of patients in the ABMS and posterior approach groups. This limitation is primarily due to the small sample size in the posterior group, which restricts the ability to detect significant differences between groups. Despite this, the study was continued to capture the outcomes associated with each cTHA approach, as increasing the sample size was not feasible given the surgeons' predominant use of the ABMS approach. Future studies should aim to include larger sample sizes or multicenter collaborations to improve statistical power and the reliability of the findings. Our results indicate that patients who received the posterior approach had a higher BMI (29.9 $\pm$ 7.0), and that all had hardware in place at the time of conversion surgery (Table 1; Table 2). While the ABMS approach is appropriate for higher-BMI patients [42] and we have demonstrated it can be used successfully in patients with hardware in place, ultimately, approach was selected in the best interest of the patient. Surgery length and blood loss were higher in the posterior approach group (Table 3), markers of surgical complexity. [21,49] Patients in this group had an ASA score of 3.0 $\pm$ 0.4 (Table 1), indicating they were much higher risk for total joint arthroplasty surgery. [50,51] The best approach to the hip for particularly high-risk patients remains under study, [52] highlighting the need for further research in understanding the impact of surgical approach to the hip on outcomes to maximize patient care.

Other limitations

Due to the use of 1 EMR at our institution, we are limited to data within our network of 10 hospitals. Therefore, if a patient were to have a complication or readmission at a hospital out of our network, it would not have been accounted for. Conversion procedures within our cohort were not analyzed independently based on prior surgical procedure. Some studies had large enough cohorts to only observe 1 type of conversion procedure, and others include arthroscopy procedures in their definition of conversion [36,53-56]. This variable definition introduces multiple challenges when comparing between cTHA studies. We found it necessary to combine all conversion procedures into 1 analysis to analyze surgical approach. Future studies would benefit from comparing the ABMS approach directly to either the posterior or direct anterior approaches, as well as addressing outcomes for specific preoperative diagnoses individually.

Conclusions

It is known that the ABMS approach is a safe and effective method for primary THA [19], but this study is the first to observe outcomes of cTHA procedures using this muscle-sparing approach. We have demonstrated that within the 90-day postoperative care period, the ABMS approach is effective and safe for cTHA when compared to the posterior approach. Patients receiving the ABMS approach underwent uneventful recovery and reported high functional scores at 1 year and final follow-up of 5.0years $\pm$2.1. There was 1 instance of reoperation, indicating 99 % implant survivorship over this period. This research aids in bridging the literature gap between cTHA and surgical approach; an analysis ie, important to advance patient care in a procedure of increased complexity.

Conflicts of interest

George Babikian receives royalties from, is on the speakers' bureau or has received paid presentations from, and is a paid consultant for Smith & Nephew. Brian J. McGrory receives royalties from Innsmed and Smith & Nephew; is on the speakers' bureau or has received paid presentations from Smith & Nephew; receives research support from Smith & Nephew and Zimmer Biomet; receives royalties or financial or material support from Springer; and is on the editorial or governing board of Arthroplasty Today and AAHKS. Adam J. Rana receives royalties from, is on the speakers' bureau or has received paid presentations from, and is a paid consultant for Smith & Nephew and is a board member of the Eastern Orthopedic Association and AAHKS. The other authors declare there are no conflicts of interest.

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CRediT authorship contribution statement

Catherine M. Call: Writing – review & editing, Writing – original draft, Visualization, Validation, Investigation, Formal analysis, Conceptualization. **Johanna Mackenzie:** Writing – review & editing, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Zoë A. Walsh:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Bailey Shevenell:** Writing – original draft, Methodology, Formal analysis, Data curation. **George Babikian:** Writing – review & editing, Supervision, Data curation, Conceptualization. **Brian J. McGrory:** Writing – review & editing, Supervision, Methodology, Data curation. **Adam J. Rana:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Formal analysis, Data curation, Conceptualization.

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