Conversion of a Fused or Ankylosed Hip to Total Hip Arthroplasty: Is the Direct Anterior Approach in the Lateral Decubitus Position an Ideal Solution?

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Background: Total hip arthroplasty (THA) using the direct anterior approach (DAA) is becoming increasingly popular due to its potential benefits over the posterolateral approach (PLA). However, few studies have compared the efficacies of these two surgical approaches in hip fusion treatment. This study compared early clinical direct anterior and posterolateral THA outcomes in hip fusion treatment.

Methods: Here, 127 hips (65 DAA, 62 PLA) were retrospectively evaluated. Early postoperative functional outcomes of DAA and PLA groups were assessed using Harris score and Oxford Hip Score (OHS) and standard anteroposterior hip radiographs. Surgical characteristics, perioperative results, and complications within 6 months postoperatively were recorded.

Results: Though baseline values were similar, Harris and OHS scores were better in the DAA group than in the PLA group at 1 and 3 months postoperatively. The average cup anteversion angle was significantly greater in the DAA group than in the PLA group (12.7° vs. 11.1°). More hips undergoing DAA were successfully orientated in both inclination and anteversion angles (46 vs. 32). Early postoperative hip function predictors were preoperative fused hip position, surgical approach, and range of motion. DAA was associated with reduced postoperative blood loss and shorter hospital stays. Furthermore, 14 vs. 8 complications occurred in the DAA vs. PLA group. Lateral femoral cutaneous nerve injuries were observed in eight hips (12.3%) of the DAA group.

Conclusion: For fused or ankylosed hips, THA using DAA in the lateral decubitus position may result in excellent prosthesis positioning and faster postoperative recovery throughout early follow-up vs. PLA.

Keywords: total hip arthroplasty, posterolateral approach, direct anterior approach, hip fusion, ankylosed hip
INTRODUCTION

A fused or ankylosed hip may be a late complication of chronic inflammatory disorders or an iatrogenic result of hip fusion (1). Hip arthrodesis is a popular salvage procedure after hip tuberculosis, septic arthritis, and severe unilateral hip trauma (2, 3). Although successful hip arthrodesis provides long-term pain relief and facilitates resumption of activities involving heavy labor, range of motion loss and gait abnormalities are noted. The contralateral hip joint, ipsilateral knee joint, and spine need to be compensated accordingly, which accelerates metamorphosis (2, 3). Therefore, total hip arthroplasty (THA) is currently considered the best option due to maintenance of hip function, sparing other joints.

Although the conversion of ankylosed or fused hips to THA has proven successful throughout long-term clinical follow-ups (1, 4), the surgical technique is challenging. Surgical exposure is difficult due to the presence of surgical scars and soft-tissue contracture. It is also difficult to obtain a clear joint space by lifting or rotating the femur. Violent operations may easily cause iatrogenic fractures due to osteoporosis-related disuse. Orienting the cup prosthesis is also technically demanding because the lumbosacral joint lacks compensation during pelvic movement. Previously, the posterolateral approach (PLA) has most often been used, since exposure is clear and extension may easily be achieved (1, 5, 6).

The direct anterior approach (DAA) in THA, first described by Judet et al. is a minimally invasive neuromuscular approach involving a minimal degree of muscle injury. It is typically performed in the supine position using a tailor-made leg-traction operation table. This approach is favored among arthroplasty surgeons due to its potential advantages over other approaches: milder pain, faster recovery, better postoperative gait, and comparatively lower dislocation rate. However, there have been concerns regarding exposure difficulties due to poor femur mobility in a fused or ankylosed hip (7) that may lead to implant mispositioning, especially in procedures performed by inexperienced surgeons. To overcome these limitations, the lateral decubitus position was attempted, and preliminary success was achieved. Studies have shown that DAA-THA in the lateral decubitus position allows for superior prosthesis placement angles and satisfactory clinical results (8, 9).

At our institute, the lateral decubitus DAA in THA has been routinely used since 2016, with encouraging intraoperative and early postsurgical outcomes. However, to date, only few studies have reported clinical outcomes of lateral decubitus DAA-THA in patients with a fused or ankylosed hip. Our hypothesis is that the DAA in the lateral position can facilitate the achievement of comparable or better clinical results than the PLA. Therefore, we compared early clinical direct anterior and posterior THA outcomes in hip fusion treatment.

Abbreviations: CI, Confidence interval; DAA, Direct anterior approach; HHS, Harris Hip Score; LFCN, Lateral femoral cutaneous nerve; OHS, Oxford Hip Score; PLA, Posterolateral approach; ROM, Range of motion; THA, Total hip arthroplasty.

MATERIALS AND METHODS

Patient Cohort

The study was conducted in accordance with the Declaration of Helsinki, with Ethics Committee approval. We retrospectively collected electronic medical records of 115 patients who underwent THA for hip fusion between January 2013 and January 2020. The inclusion criteria were (1) unilateral or bilateral hip arthroplasty for fused hip; (2) DAA approach or posterolateral approach for THA; and (3) at least 1-year of follow-up. Exclusion criteria were (1) history of lower limb nerve injury or lower limb surgery; (2) serious underlying diseases, such as severe cardio-cerebrovascular disease, liver and kidney failure; or (3) incomplete medical records.

Surgical Technique

The surgical technique used was retrieved from medical records. All procedures were performed by the same senior surgeon. Patients were placed in the standard lateral decubitus position on an ordinary operation table.

DAA-THA was conducted through Huerter’s interval (Supplementary Video 4). An incision was initiated 3 cm posterolateral of the anterior superior iliac spine and extended distally 8–12 cm long toward the fibular head. Fascia was separated along the tensor fascia lata surface, and the tensor fascia lata and sartorius were passively separated inward. The ascending branches of the lateral circumflex vessels were ligated or cauterized. After releasing the rectus femoris muscle and incising the anterior joint capsule, the fused hip joint and surrounding hyperplastic osteophytes were completely visible (Figure 1). Two osteotomies of the femoral neck were performed based on preoperative templates. The femoral head, chiseled by the osteotome, was retrieved. The glenoid labrum, articular capsule, and osteophyte were removed. The acetabulum was reamed to permit the proper positioning of the cup at 35–45° inclination and 7–17° anteverision. The femur was prepared by placing the affected leg in flexion, adduction, and internal rotation (Supplementary Files Case 1). This was followed by posterolateral hip capsule excision. Sequential external circumflex muscle groups were released until the proximal femur was lifted. The femur was reamed under direct vision, and the prosthesis was implanted. Tranexamic acid (1.0 g) was applied locally, and routine closure of the incision was performed.

PLA operations were performed using the Kocher-Langenbeck approach. An arc incision was made 1 cm posterior to the greater trochanter, extending ~10 cm to the distal end. Then, the iliobibial band was split, the gluteus maximus was released, the short external circumflex muscle and joint capsule were cut, and femoral neck osteotomy was performed. Acetabular and femoral prostheses were implanted in the same manner as was described for the DAA. Similar uncemented prosthetic implants have been used in these surgeries.

Postoperative Rehabilitation

Prophylactic antibiotics (cefuroxime) and thromboprophylaxis (low-molecular-weight heparin) were administered to all patients. Partial weight-bearing physical exercise was begun 1
day postoperatively. No hip joint movement was restricted in the DAA group, while routine hip joint precautions were indicated in the PLA group.

Radiographic Evaluations
Standard anteroposterior hip radiographs were obtained preoperatively, immediately postoperatively, and at the last clinical visit. The inclination angle of the acetabular cup was measured using Widmer's method and the anteverision angle was determined using Lewinnek's method (10). The Danoff safety zone was used to evaluate the cups position, and a cup with $30^\circ$-$50^\circ$ of abduction and $5^\circ$-$25^\circ$ of anteversion was considered successful (11). All radiological data were evaluated by two independent radiologists.

Functional Evaluation
Preoperative, postoperative, and follow-up statistics were collected. follow-up usually occurred at 1, 3, 6, and 12 months postoperatively and yearly thereafter. At each follow-up, joint function was assessed using Harris Hip Score (HHS) and Oxford Hip Score (OHS).

Perioperative Characteristics
Postoperative blood loss volume was calculated based hemoglobin concentration before and after surgery via Nadler's method (12). Preoperative and postoperative leg length discrepancy were measured using full-length, lower extremity radiographs. In addition, the incidence of complications, including proximal femoral fractures, superficial incisional complications, wound infection, nerve injury, dislocation, and deep venous thrombosis, were recorded.

Statistical Analysis
Descriptive statistics summarized characteristics and findings. Continuous variables were expressed as mean $\pm$ standard deviation, and the Kolmogorov-Smirnov normal test was used to evaluate digital sample distributions. Between-group differences were compared using the two-tailed independent sample $t$-test or Mann-Whitney $U$-test. Categorical variables were expressed as frequency and percentage, and outcomes were compared using the Chi-square or Fisher's exact tests. Linear regression equations were used to describe acetabular cup angle changes due to surgical experience. HHS after 1 month of follow-up were divided into four grades, as follows: excellent (>80 points), good (70–79 points), fair (60–69 points), and poor (50–59 points) (Supplementary Figure 1). Ordinal regression was used to analyze independent risk factors affecting postoperative HHS. The factors considered in the model included age, sex, body mass index, course of disease, etiology, fused position, preoperative HHS, surgical approach, operative time, intraoperative blood loss, prosthesis position, complications, and joint range of motion (ROM). Mediation of ROM in the relationship between fusion type and HHS at 1 month of follow-up was tested, while controlling for confounding factors (sex, age, disease course, and surgical approach). SPSS 26 software (SPSS, Armonk, NY) was used for statistical analyses, and $p < 0.05$ was considered statistically significant.

RESULTS
One hundred-two (127 hips) of 115 patients initially considered were included in the study (Figure 2). The average follow-up was 37.9 $\pm$ 18.3 months (12.0–81.2 months). Causes of hip fusion were ankylosing spondylitis and suppurative hip arthritis. Primary indications for THA were low back pain (59 cases, 46.5%), ipsilateral knee joint pain (17 cases, 13.4%), homolateral or contralateral hip pain (44 cases, 34.6%), and severe claudication (7 cases, 5.5%). Baseline characteristics of both groups were similar (Table 1).

Functional Outcomes
Objective and subjective functional status were evaluated using HHS and OHS scores. Overall, status significantly improved postoperatively (Figure 3). Mean HHS scores of the DAA group were significantly higher than those of the PLA group at 1 and 3 months postoperatively (71.8 $\pm$ 8.3 vs. 64.5 $\pm$ 6.7, $p < 0.001$; 81.6 $\pm$ 6.7 vs. 77.8 $\pm$ 4.2, $p < 0.001$, respectively). The difference was mainly attributable to feature scores. Compared to the PLA group, an increased percentage of patients in the DAA group abandoned walking aids (39 [60.0%] vs. 13 [21.0%] 1 month postoperatively, $p < 0.001$; 59 [90.8%] vs. 45 [74.2%]) at postoperative month three, $p$
FIGURE 2 | Study design and flowchart.

TABLE 1 | Demographics and baseline characteristics of included cases.

|                | DAA (n = 65) | PLA (n = 62) | P-Value |
|----------------|--------------|--------------|---------|
| Age (y)        | 46.0 ± 12.9  | 44.7 ± 11.0  | 0.527   |
| Gender (Male/female) | 51/14        | 49/13        | 0.937   |
| BMI            | 23.5 ± 3.6   | 23.5 ± 4.0   | 0.998   |
| Preop VAS      | 3.3 ± 0.6    | 3.2 ± 0.7    | 0.487   |
| Preop HHS      | 44.4 ± 9.3   | 47.0 ± 10.2  | 0.141   |
| Preop LLD      | 2.6 ± 1.5    | 2.3 ± 1.3    | 0.206   |
| Causing disease (AS/ purulent arthritis) | 48/17        | 42/20        | 0.449   |
| Course of disease (y) | 18.5 ± 9.5   | 15.7 ± 7.5   | 0.127   |
| AS             | 39.9 ± 12.1  | 42.0 ± 15.2  | 0.646   |
| Fuse position (Flexural/ extended) | 33/32        | 35/27        | 0.521   |

DAA, means direct anterior approach; PLA, posterolateral approach; BMI, body mass index; preop, preoperative; VAS, Visual Analog Scale; HHS, Harris Hip Score; LLD, Leg Length Discrepancy; preop, preoperative.

One year postoperatively, no significant between-group differences were observed (85.4 ± 5.5 vs. 85.1 ± 4.3, p = 0.731). For 1-month to 1-year follow-up, the DAA group had better OHS scores than the PLA group (p < 0.05). No significant difference between-group difference in ROM was observed 1 year postoperatively (Supplementary Table 2).

Prosthesis Information
A BetaCup (LINK, Germany) was used in 27 (21.3%) hips, a CombiCup (LINK, Germany) in 82 (64.5%), and a Trident cup (Stryker, USA) in 18 (14.2%). The bearing type included ceramic on ceramic in 106 (83.5%) hips, ceramic on polyethylene in 16 (12.6%), and metal on metal in 5 (3.9%). An LCU femoral stem (LINK) was used in 109 (85.8%) hips, whereas an Accolade stem was used 18 (14.2%).

Radiological Outcomes
The postoperative pelvic orthographic images revealed that the cup anteversion angle of the DAA group was significantly larger than that of the PLA group (12.7° vs. 11.1°, p = 0.012). However, average cup inclination angles and femoral stem alignment did not differ (Table 2). In total, 46 hips of the DAA group (70.8%) and 32 of the PLA group (51.6%) were successfully placed within the Danoff safety zone (p = 0.027, Figures 4, 5). Early in the surgeon’s learning curve for the DAA, inclination and anteversion acetabular cup angles periodically fluctuated around 38.36° and 11.71°, respectively, and gradually stabilized. Residual acetabular inclination angle error gradually decreased with surgical experience. Accordingly, the absolute value of residual acetabular inclination angle was linearly associated with time (β = −0.05711, R² = 0.1028, p < 0.05, Figure 6). Acetabular anteversion deviation also seemed to decrease with surgical experience increased. A linear regression was attempted, but results were not significant (R² = 0.050, p = 0.073, Figure 6).

Postoperative Hip Joint Function
A logistic regression model identified the following risk factors for poor postoperative hip function (Table 3): preoperative fused hip position (odds ratio [OR]: 2.35, 95% confidence interval [CI]: 1.12–4.93, p = 0.024), surgical approach (OR: 3.11, 95% CI: 1.42–6.81, p < 0.01), and early postoperative ROM (OR: 1.1, 95% CI: 1.01–1.09, p = 0.02). It was revealed that early postoperative ROM mediated 19.8% of the total effect of fused hip position on postoperative HHS 1 month postoperatively, (Supplementary Tables 3, 4).

A comparison of early postoperative ROM and HHS was made between flexural and extended hips, which revealed that extended hips had improved ROM and HHS. Interestingly, a subgroup
Dong et al. Lateral DAA in Fused Hip

**Figure 3** | Line chart which shows the comparisons of Harris score (A) and OHS scores (B) between patients in DAA group and PLA group. The error bars indicate the standard deviation.

**Table 2** | Implant alignment.

|                | DAA (n = 65) | PLA (n = 62) | P-Value |
|----------------|--------------|--------------|---------|
| Cup alignment  |              |              |         |
| Inclination    | 39.3 ± 5.5   | 39.6 ± 6.0   | 0.760   |
| Anteversion    | 12.7 ± 3.5   | 11.1 ± 3.9   | 0.013   |
| Fall in the safe zone | 46 (70.8%) | 32 (51.6%) | 0.027   |
| Stem alignment |              |              |         |
| Neutral        | 47 (72.3%)   | 38 (61.3%)   | 0.187   |
| Varus          | 7            | 10           |         |
| Valgus         | 11           | 14           |         |

DAA, means direct anterior approach; PLA, posterolateral approach.

**Discussion**

Fused or ankylosed hips are highly inconvenient, and studies have shown that THA surgery is an effective and economically efficient therapy for affected patients (1, 3, 4). Converting hip fusion to THA is technically challenging. Although there have been many reported successes, surgical difficulties and trauma are concerning (2, 4). DAA-THA is minimally invasive. It has been assumed that hip deformity and fusion are contraindications for DAA surgery. However, recent knowledge indicates the technique can be performed smoothly in many situations and has potential advantages. To date, few studies have compared outcomes of lateral decubitus DAA and PLA-THA in patients with hip fusion. This study revealed that patients receiving DAA-THA recovered faster than those who underwent PLA-THA, indicating that DAA-THA may be an effective solution for converting fused or ankylosed hips to THAs.

The DAA facilitates rapid rehabilitation because it causes less muscle damage and less bleeding. Postoperatively, patients are quickly able to bear weight and perform functional exercises, and risk of posterior dislocation is low. Rapid recovery after DAA-THA is well known (13–15). Bremer et al. validated this by showing that gluteal muscles in patients who underwent DAA were well preserved via MRI (16). Wu et al. reported that DAA may be successfully used to treat hip fusion (17). Patients who underwent DAA surgery had improved pain, joint motion, and functional evaluation scores. In addition, DAA surgery also includes advantages of preservation of external rotation and abductor muscle strength (18, 19), which is of great significance in fusion of hip joints. On the other hand, a large number of patients undergoing conventional initial total hip replacement have benefited from rapid recovery using the DAA approach. Undoubtedly, this is of huge attraction for doctors and patients in complex cases such as hip fusion. Herein, functional scores of patients undergoing DAA surgery were significantly higher than those of patients undergoing PLA. Interestingly, an analysis revealed that the phenomenon was apparent only in the hips that underwent PLA surgeries (Table 4).

**Perioperative Outcomes and Complications**

Perioperative blood loss of the DAA group was less than that of the PLA group. In addition, DAA-THA was associated with a shorter hospital stay than PL A-THA (Table 5).

Fourteen complications (21.5%) occurred in the DAA group vs. 8 (12.9%) in the PLA group. Intraoperative proximal femoral fractures occurred in eight hips (three and five in DAA and PLA groups, respectively). Fractures were directly reduced and fixed using steel wire. Superficial wound complications occurred in 6 hips (three in each group). Lateral femoral cutaneous nerve (LFCN) injuries were observed in 8 hips (12.3%; all the DAA group); 4 hips (50%) of the surgeon’s first 33 cases and 4 hips (50%) throughout the surgeon’s latter 32 cases. Symptoms in 5 hips (83.3%) were alleviated at the last follow-up (Supplementary Table 5).
of HHS during the same postoperative period revealed that the difference between the two groups was mainly due to functional rather than pain scores, possibly due to the improved functional recovery and the ability to lose crutches or walkers earlier in the recovery period. Therefore, patients who underwent DAA tended to be satisfied with their hips. The largest between-group difference observed was between early OHS scores of DAA and PLA groups, which was likely due to the fact that the scoring system is based on patient self-evaluation. In contrast, OHS is based on more detailed evaluation items, which less significantly reflect a ceiling effect than other patient-reported outcome evaluation systems (20).

Previous studies have shown DAA can achieve the same excellent acetabular cup positioning as can be achieved with PLA (21–24). Zhao et al. compared the acetabular position of patients who underwent THA using the DAA or PLA. The DAA was associated with lessened acetabular cup abduction angle fluctuation (25). Herein, prosthesis orientation and alignment differences between groups were not significant. Therefore, we used the modified Lewinneck safety zone standard to evaluate acetabular prosthesis installation, which revealed that more acetabular cups in the DAA group were ideally positioned with respect to anteversion and abduction. This may be related to the fact that the acetabulum is exposed more easily in DAA-THA in the lateral recumbent position. Although deviation was large in the early stages, early clinical outcomes were not affected. This imperfection was quickly eliminated as the surgeon gained experience. Parameters of anterior approach surgery can be quickly stabilized throughout the surgeon’s learning curve. In this presented study, the DAA group quickly
FIGURE 6 | Scatter plot showing the anteversion and inclination angles of the acetabulum in the DAA group. (A) The inclination angle of the acetabulum changes with the learning curve and its linear regression equation (non-significant). (B) The residual deviation of inclination from the target. (C) The absolute value of the residual deviation of the acetabular inclination angle and its linear regression. (D) The anteversion angle of the acetabulum changes with the learning curve and its linear regression equation (non-significant). (E) The residual deviation of anteversion from the target. (F) The absolute value of the residual deviation of the acetabular anteversion and its linear regression.

TABLE 3 | Summary of multivariable ordinal logistic regression for 1 month follow-up.

| Factors                      | P-value | Odds ratio (95% Confidence interval) |
|------------------------------|---------|-------------------------------------|
| Age (years)                  | 0.141   | 1.030 (0.990, 1.072)                 |
| Gender (female)              | 0.158   | 0.469 (0.164, 1.341)                 |
| Course (years)               | 0.082   | 0.966 (0.928, 1.004)                 |
| BMI                          | 0.594   | 0.975 (0.889, 1.069)                 |
| Cause (purulent arthritis)   | 0.838   | 0.872 (0.234, 3.251)                 |
| Fuse position (flexural)     | 0.024   | 2.348 (1.119, 4.926)                 |
| Preop-HHS                    | 0.892   | 0.998 (0.963, 1.034)                 |
| Surgical approach (PLA)      | 0.005   | 3.110 (1.421, 6.809)                 |
| Operation time               | 0.320   | 1.005 (0.995, 1.016)                 |
| Blood Loss                   | 0.911   | 1.000 (0.997, 1.002)                 |
| Cup orientation (not successful) | 0.214   | 1.609 (0.760, 3.406)                 |
| Stem coronal alignment (not successful) | 0.876   | 0.944 (0.456, 1.954)                 |
| Complication                 | 0.274   | 1.678 (0.664, 4.237)                 |
| ROM                          | 0.02    | 1.050 (1.008, 1.093)                 |

DAA, means direct anterior approach; PLA, posterolateral approach; BMI, body mass index; ROM, Range of Motion; HHS, Harris Hip Score; preop, preoperative.

TABLE 4 | Harris scores and ROM of patients of two groups for 1-month follow-up.

|                      | ROM     | P-Value | Harris  | P-Value |
|----------------------|---------|---------|---------|---------|
| Fused position       | 139.6 ± 9.7 | 0.003   | 66.3 ± 8.6 | 0.004   |
| Flexural (68)        | 144.8 ± 9.7 | 70.5 ± 7.7 |
| Flexural (32)        | 146.1 ± 9.9 | 73.5 ± 7.6 |
| Extended (27)        | 134.6 ± 9.1 | 0.001   | 62.5 ± 6.4 | 0.008   |
| Flexural (35)        | 143.3 ± 9.3 | 67.0 ± 6.4 |

DAA, means direct anterior approach; PLA, posterolateral approach; ROM, Range of Motion.

patients, those with ankylosing spondylitis had a higher rate of postoperative dislocation due to spinopelvic stiffness (28). In the early cases of ankylosic hip replacement surgery, even in patients undergoing posterior approach surgery, a considerable proportion experienced anterior dislocation (29). For such patients, the “safe zone” was narrow and required more accurate prosthesis positioning.

It was once believed that placing the femoral component in the proper supine position in DAA-THA would be difficult due to problems with elevating the proximal femur (7, 30). It is sometimes necessary to fold the operating table so that the femur
TABLE 5 | Surgical characteristics and perioperative results.

|                  | DAA (n = 65) | PLA (n = 62) | P-Value |
|------------------|--------------|--------------|---------|
| Operation time(min) | 82.2 ± 34.1 | 95.0 ± 43.1 | 0.063  |
| Blood Loss       |              |              |         |
| Intraoperation    | 185.8 ± 164.8 | 251.6 ± 167.7 | 0.028  |
| Postop day 1      | 588.3 ± 233.3 | 768.6 ± 304.0 | 0.000  |
| Postop day 3      | 831.1 ± 307.0 | 1046.2 ± 349.1 | 0.000  |
| Length of stay    | 6.4 ± 3.4    | 7.9 ± 3.4    | 0.014  |
| Postop LLD        | 0.4 ± 0.5    | 0.4 ± 0.5    | 0.486  |
| Blood transfusion  | 4            | 7            | 0.476  |

DAA, direct anterior approach; PLA, posterior lateral approach; ROM means Range of Motion; LLD, Leg Length Discrepancy.

is extended to complete this operation. Even so, the extent of hip extension is still limited. However, in the lateral position, the hip joint can be extended without restriction, making it easier than ever to release the posterior joint capsule and expose the proximal femur (8). With DAA in the supine position, the ipsilateral knee is in flexion in order to expose the proximal femur. In the lateral position, the knee joint is straight. This will help relax the tensor fasciae latae and reduce incisional tension. Herein, femoral prosthesis placement of the two groups assessed did not significantly differ.

The following risk factors of hip joint surgery affecting early function have been previously identified: surgical approach, preoperative HHS score, comorbidities (1, 31, 32). Herein, the preoperative fusion type, surgical approach, and early postoperative joint ROM were independent risk factors that affected early postoperative HHS. In a fused hip in flexion, adequate release of the anteriorly contracted capsule via PLA was not an easy job. This stage requires extra care to avoid damage to the main blood vessels so that it is sometimes omitted intentionally. Long-term contracture of soft tissues and inadequate release will cause joint extension limitation in the early postoperative period in some patients, directly resulting in inferior HHS. Early postoperative ROM is likely to mediate the effect of hip fusion type on early postoperative HHS. Limited joint mobility may adversely affect the patient’s gait and daily life, further affecting HHS. In contrast, it’s easy and safe to release capsular ligament from the front view. This facilitates ROM improvement, even in flexural-fused hips (Supplementary Files Case 2–7, Supplementary Videos 1–3). Joint extension limitation in these patients can be gradually improved with continuous rehabilitation. At the 1-year postoperative follow-up, no significant between-group differences in ROM nor HHS were observed.

Compared with PLA, DAA-THA has obvious advantages in terms of blood loss and length of stay. Better perioperative outcomes verified the superiority of DAA as a minimally invasive surgery. Regarding postoperative complications, no significant between-group difference regarding in the incidence of complications was observed. LFCN injury was a unique complication of DAA. In our study, LFCN occurred 4 of the first 33 and the last 32 hips, indicating that the learning curve of the surgeon did not significantly contribute to postoperative LFCN injury. The position of the incision (33), small femoral offset (34), and sartorius and tensor fasciae latae muscle separation may contribute to LFCN injury (8). At the six-month postsurgical follow-up, LFCN symptoms were relieved in five patients (83.3%). Despite the occurrence of this complication, clinical outcomes of the DAA group were not worse than those of the PLA group. Hence, fear of postoperative LFCN injury should not cause novice surgeons to avoid selecting the DAA approach.

This study has several limitations. First, it was a retrospective study, patients were not randomly assigned to two groups. The early cases in this cohort are mainly using PLA, while the later cases are DAA since we became familiar with this approach (Supplementary Figure 2). However, the rarity of fused hip cases makes conducting a large-scale, randomized controlled trial impractical. When analyzing the characteristics of cases retrospectively, we set up strict inclusion and exclusion criteria to minimize selection bias. There is no difference between the baseline data of the two groups of patients. Second, since the surgical technique is relatively new, long-term clinical results remain unavailable. Given our limited knowledge of hip fusion treatment with DAA-THA, results of this study are meaningful. Mid- and long-term follow-up will be performed to further assess the effect of this technique in the future. Especially for patients with extended hip fusion (because the proximal femur leans forward), DAA-THA facilitates the release of external rotators and the posterior capsule to expose the proximal femur.

CONCLUSIONS

For patients with complex hip fusion, lateral decubitus DAA-THA may be an ideal option if supine DAA is difficult due to a lack of dedicated operating equipment. Compared with posterolateral THA, this technique seems to yield satisfactory clinical and radiological results.

DATA AVAILABILITY STATEMENT

All relevant data are included in the report and its associated files.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the First Affiliated Hospital of USTC. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

XZ: conceptualization, and methodology. JD and LK: formal analysis, and investigation. JD: writing—original draft preparation. SZ: writing—review and editing. CZ: resources. JW, CZ, and XS: supervision. All authors contributed to the article and approved the submitted version.
FUNDING
This work was supported by the National Natural Science Foundation of China (Grant No. 81871788), the Key Research and Development Program of Anhui Province (No. 202004j07020013), the project for Science and Technology leader of Anhui Province (Grant No. 2018H177), the Anhui Provincial Postdoctoral Science Foundation (Grant No. 2019B302), the Scientific Research Fund of Anhui Education Office (Grant No.2020jxjm2316), the National Natural Science Foundation of Anhui Province(2108085QH319), and the Fundamental Research Funds for the Central Universities (WK9110000173).

SUPPLEMENTARY MATERIAL
The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsurg.2021.819530/full#supplementary-material

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