

Supercapsular Percutaneously-Assisted Approach Versus Conventional Posterolateral Approach for Primary Total Hip Arthroplasty: A Prospective Randomized Controlled Study

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Abstract

Background: Super capsular percutaneously-assisted total hip (Super PATH) approach has been regarded as one of minimally invasive and muscle sparing technique, which accesses the hip maintaining integrity of the external rotators and capsule. The purpose of this study was to compare the Super PATH approach with the conventional posterolateral approach in terms of early clinical outcomes and radiological results.

Methods: This prospective randomized controlled single blinded study enrolled patients who underwent unilateral primary THA between June 2020 and August 2021. The demographic data, perioperative status [operative time, incision length, total blood loss, serum marker, and length of hospital stay (LHS)], pain visual analog scale (VAS), and Harris Score (HS) were evaluated and compared between the groups.

Results: Compared with the PLA group, the Super PATH group had a shorter incision length, lower pain VAS sores within 1 months and better HS within 3 months after operation, the difference was statistically significant ($P < 0.05$). However, the Super PATH group had a longer operative time, more total blood loss, the difference was statistically significant ($P < 0.05$). The mean complication rate, blood transfusion rate and LHS were similar between two groups ($P > 0.05$). The VAS and HS were similar between the two groups at 1 year after surgery ($P > 0.05$). Serum levels of C-reactive protein (CRP), erythrocyte sedimentation rate (ESR) and creatine kinase (CK) (within 2 weeks postoperatively) were similar between the groups ($P > 0.05$). The Super PATH group had a larger acetabular inclination and anteversion ($P < 0.05$), but it was all within Lewinski's safe zone. Leg length discrepancy > 1 cm were more common in the Super PATH group, but the difference was not significant ($P > 0.05$).

Conclusion: This study reveals that the Super PATH technique was associated with lower pain levels, and higher physical function than conventional posterolateral approach. However, it had a longer operative time and more blood loss.

Keywords: Total hip arthroplasty; Super capsular percutaneously assisted; Minimally invasive; posterolateral approach

Introduction

Total hip arthroplasty (THA) has been regarded as one of the most successful orthopedic reconstructive procedures for patients who suffer from end-stage hip osteoarthritis(OA) and osteonecrosis of femoral head(ONFH). Several approaches to the hip joint in THA have been described and modified by various authors. They are divided into two main groups: conventional and minimally invasive approaches. Due to excellent exposure to the hip, the conventional posterolateral approach (PLA) is the most widely utilized approach for THA [1]. However, PLA have some respective disadvantages, including massive tissue damage, possible postoperative dislocation, and delayed postoperative rehabilitation [2].

The minimally invasive approaches for THA are divided into two types: muscle-sparing and miniincision approaches. Miniincision approaches only shortens the incision, it still need to cut off the muscle the hip muscles as the traditional approach[3]. Findings in current literature did not show remarkable benefits in outcomes of minimally invasive approaches compared to conventional approaches in hip Replacement[3-5]. The supercapsular percutaneously-assisted total hip (Super PATH) technology, runs between the gluteus minimus and piriformis without cutting off any hip muscles and therefore preserves the integrity of muscles surrounding the hip joint, first reported by Dr. Chow[6]. In relative publications, observations of this surgical technique have shown some advantages including a shorter length of hospital stay, less blood loss, less postoperative pain, satisfactory radiographic outcomes, and excellent early functional results [7].

The purpose of the current study was to evaluate the early postoperative outcomes between the PLA and the Super PATH for primary THA. Our hypothesis was that the use of the SuperPATH would result in a shorter length of hospital stay (LHS), less blood loss, less postoperative pain and soft tissue damage, and earlier return of function without an increase in complication rates or malpositioned prostheses.

Methods and Materials

Patients

The present prospective randomized controlled single blinded study enrolled a total of 120 patients who diagnosed as OA or ONFH and received primary THA in our hospital from June 2020 to August 2021. Patient characteristics [age, sex, body mass index (BMI), comorbidities, and American Society of Anesthesiologists (ASA) grade] were collected to determine whether the two cohorts were comparable at baseline (Table 1). The exclusion criteria included previous surgery to the hip and stiff hip joints. Of the 120 patients assessed for eligibility, 11 failed to meet the inclusion criteria (previous surgery to the hip in 7 patients and 4 stiff hip joints) and 9 declined to participate; the remaining 100 patients were randomized to the two groups (Super PATH group and PLA group). Two patients did not receive allocated intervention in the Super PATH group due to the approach was changed to the traditional approach during surgery. Two patients in the Super PATH group were lost to follow-up and three in the PLA group (Figure.1).

Variables	Super PATH (n=50)	PLA (n=47)	P value
Age, year	57.08±12.13	59.94±10.75	0.199
BMI, kg/m ²	25.82±4.67	27.44±6.05	0.14
Sex, male/female	23/27	20/30	0.545
ASA(I/II)	35/15	30/20	0.295
Pathological type, n (%)			0.147
OA	15 (30%)	28 (56%)	
ONFH	35 (70%)	22 (44%)	

Table 1: Demographic characteristics

OA, osteoarthritis; ONFH, osteonecrosis of femoral head; ASA, American Society of Anesthesiologists

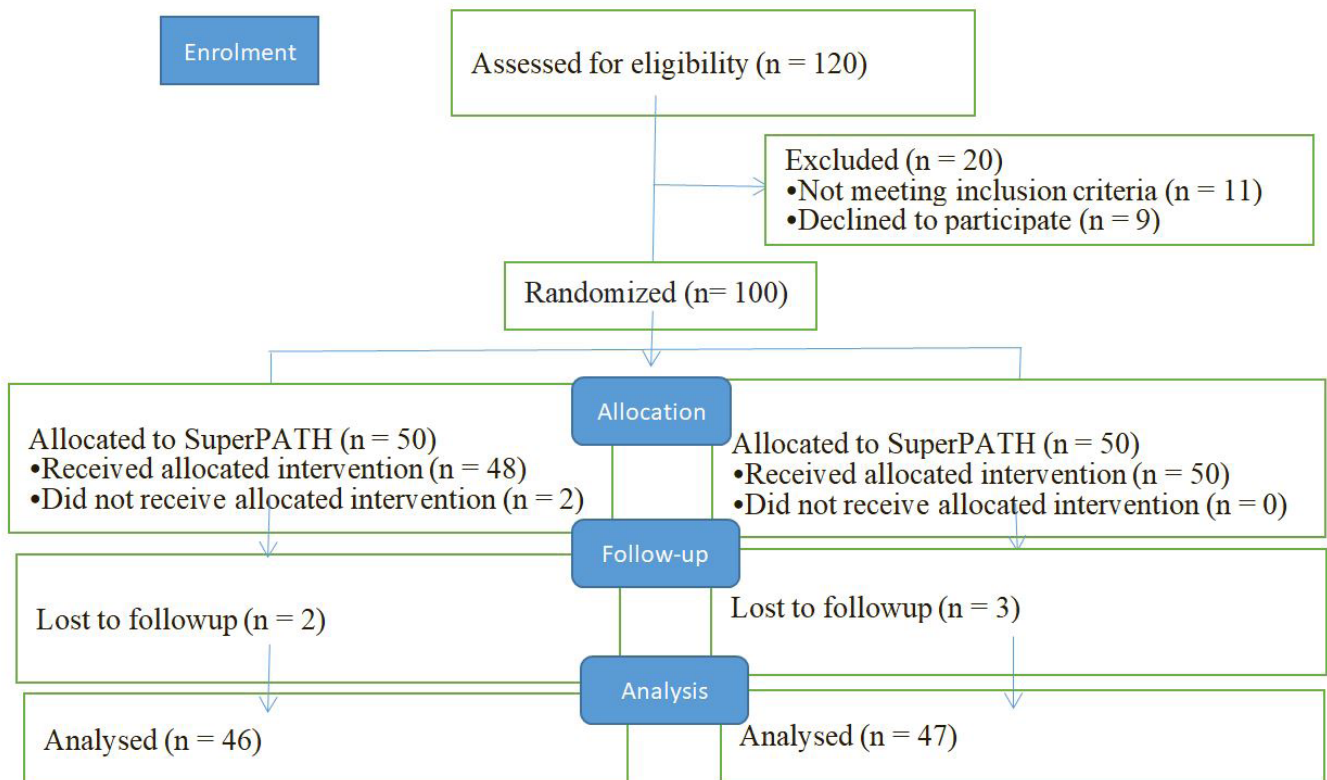


Figure 1: Patient flow

The present study was approved by the Ethic Committee of Gui Gang city people's Hospital (approval number GYLLPJ-20210813-21). The study was conducted according to the principles of the Declaration of Helsinki (as revised in 2013).

Surgical strategy

All surgical procedures were completed by the same team, led by one senior surgeon (Fengping Gan) who were experienced in using the PLA approach and trained in the department's established use of Super PATH technology.

The Super PATH technology was performed as previously described [8]. The piriformis was loosened from greater trochanter attachment if it was too strong to affect surgical visual field, and then was sutured to original position after surgery. The PLA was carried out as Sierra et al described [9]. The artificial joint prostheses were purchased from two commercial company (Super PATH group: Microport Orthopaedics Inc, CHINA; PLA group: Zimmer Biomet incorporated, USA).

Postoperative management

Standardized postoperative care was provided, including infection prophylaxis, venous thromboembolism prevention, nausea and vomiting management, wound care, and functional rehabilitation. Postoperative pain was treated with multimodal analgesia, including patient-controlled analgesia, nonsteroidal anti-inflammatory drugs, transdermal patch, and central analgesics. All patients' rehabilitation exercises were carried out as planned. On day 1 after the operation, the patients were allowed protected, full weight bearing and walking with a walker.

Outcome evaluation

The general demographic characteristics including age, BMI and sex comorbidities, and ASA grade were collected. Perioperative data including operative time (skin-to-skin), total blood loss (calculated by applying the Gross and Nadler formulas, as previously described [10, 11] incision length, pain VAS, HS, and LHS were analyzed. Serum levels of C-reactive protein (CRP), erythrocyte

sedimentation rate (ESR) and creatine kinase(CK) were measured before and 3d ,14d after surgery using an automatic biochemical analyzer. The incidence of postoperative complications, including infection, dislocation, periprosthetic fractures, leg length discrepancy(LLD) and venous thrombotic events(VTE) was recorded. The angles of anteversion and abduction of acetabular cup were measured by X-ray immediately after surgery. All patients were followed up at least 1 year.

Statistical analysis

Statistical analysis was carried out using the SPSS®version 22.0 program (SPSS Inc., Chicago, USA). The clinical data and radiographic parameters were expressed as mean \pm standard deviation. The Kolmogorov-Smirnov test was used to determine the normal distribution. For comparisons, univariate analyses were used for categorical variables by the Chi-square test in variables with normal distribution and the Mantel-Haenszel test for non-parametric data, and Student's t-test or the Mann-Whitney U test in continuous variables. Multi-factor analysis of variance was adopted for assessing the postoperative serum markers, HS and VAS score. $P < 0.05$ was considered statistically significant.

Results

Surgical results

Compared with PLA group, the Super Path group had a shorter incision length, longer operative time and more total blood loss($P < 0.05$). However, blood transfusion rate and complication rate were comparable between the two groups ($P > 0.05$) (Table 2). A single posterior dislocation occurred 7 days after operation in the PAL group and was successfully treated by closed reduction with epidural anesthesia, two dislocations occurred within 2 hours after operation in the Super PATH group and successfully treated by closed reduction without anesthesia. No superficial and deep infection was found in the two groups. There were two deep-vein thrombosis (DVT) in the PLA group. There was one undisplaced acetabular fracture treated with conservative treatment in the Super PATH group.

Variables	Super PATH (n=50)	PLA (n=50)	P value
Operative time, min	79.3 \pm 13.7	54.5 \pm 6.2	0
Total blood loss, mL	708.1 \pm 80.1	635.2 \pm 98.0	0
Blood transfusion rate, n (%)	5(10.9)	3(6.4)	0.735
Incision length, cm	8.0 \pm 0.8	14.2 \pm 1.9	0
LHS, d	6.2 \pm 0.9	7.6 \pm 1.2	0.013
Complication rate,n(%)	3(6.5)	3(6.4)	0.651

Table 2: Perioperative data for two groups

LHS, length of hospital stay

Perioperative Serum Markers

No significant was found for levels of serum markers before the surgery,serum markers showed equivalent trends in both groups within the 2 weeks postoperatively ($P > 0.05$).Serum CRP,CK and ESR levels significantly increased on the third post-operative days,and decreased gradually to the normal range on the 14th day after surgery.No significant difference was found in CK, ESR and CRP between the two groups on the 3rd and 14th day after surgery ($P > 0.05$).Multivariate analysis of variance showed that there were no significant differences in the effects of surgical methods on Serum CRP,CK and ESR (CRP, $F=0.895,P =0.348$;ESR, $F=1.278,P =0.278$;CK, $F=0.614,P=0.462$). (Table 3 and Figure 2)

Variables	Super PATH (n=50)	PLA (n=48)	P value
CRP, mg/L Before	3.45±2.09	3.99±2.44	0.234
day 3	34.85±14.45	31.95±15.61	0.383
day14	5.40±3.58	5.57±2.73	0.79
F=0.895			P=0.348
ESR, mm/hBefore	20.10±9.96	19.20±10.51	0.661
day 3	44.76±13.78	42.10±11.94	0.305
day 14	26.04±8.85	25.50±7.62	0.744
F=1.278			P=0.278
CK, U/LBefore	87.60±32.87	90.46±33.36	0.667
day 3	691.42±92.16	703.00±91.14	0.529
day 14	92.90±32.29	85.56±35.35	0.281
F=0.614			P=0.462

Table 3: Perioperative changes of serum markers

CK, creatine kinase; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate

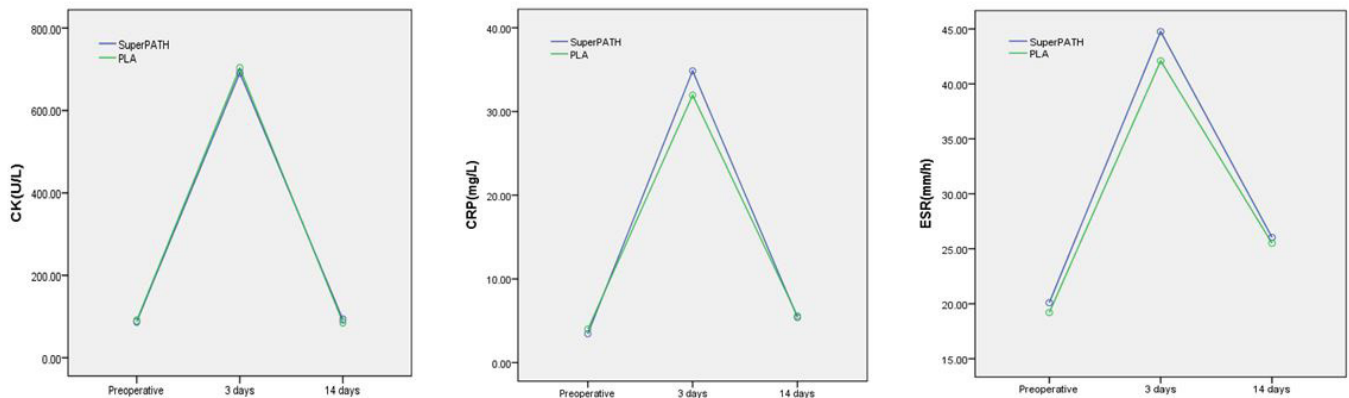


Figure 2: Perioperative changes of serum markers, including creatine kinase (CK), C-reactive protein (CRP), and the erythrocyte sedimentation rate (ESR), after total hip arthroplasty with either the supercap- sular percutaneously-assisted total hip (Super PATH) or posterolateral approach (PLA)

Clinical and Radiological Results

The VAS scores and HS were comparable before surgery between the two groups ($P>0.05$). After surgery, the VAS scores gradually and significantly decreased, while the HS markedly and gradually increased compared with the values before the surgery. Pain VAS was significantly lower in the SuperPATH group compared with the PLA group on postoperative day 3, day 14 and month 1 ($P<0.05$). No significant difference was found at 3 month and 1 years after surgery ($P>0.05$). HS was higher in the SuperPATH group compared with the PLA group at 1 mon and 3 mon postoperatively ($P < 0.05$). The VAS and HS were similar between the two groups at 1 year after surgery, no significant difference was found ($P>0.05$). Multivariate analysis of variance showed that there were statistically significant differences in the effects of surgical methods on HS and pain VAS (HS, $F=19.762$, $P = 0.000$; VAS, $F=22.018$, $P = 0.000$). (table 4 and Figure 3)

Variables	Super PATH (n=50)	PLA (n=47)	P value
Pain VAS Before	4.48±0.84	4.50±0.86	0.907
day 3	5.04±0.57	6.42±0.61	0
day 14	3.60±0.49	4.62±0.49	0
month 1	1.90±0.46	2.62±0.49	0
month 3	0.92±0.34	1.00±0.53	0.374
year 1	0.26±0.44	0.28±0.45	0.824
F=22.018			P=0.000
HS Before	37.72±4.57	38.04±5.58	0.754
month 1	82.42±3.42	76.74±2.88	0
month 3	89.90±2.23	85.92±2.26	0
year 1	93.72±1.88	93.42±1.60	0.394
F=19.762			P=0.000

Table 4: Clinical assessment tool results during the follow-Up of the 2 cohorts. VAS visual analog scale, HS Harris score

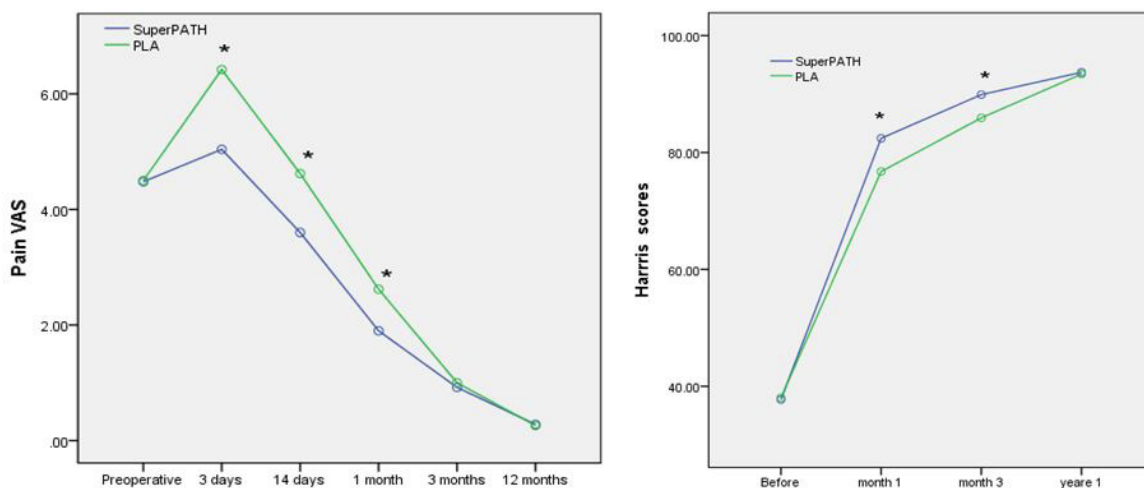


Figure 3: Perioperative changes in pain visual analog scale (VAS) and Harris Score after total hip arthroplasty with either the supercapsular percutaneously-assisted total hip (SuperPATH) or posterolateral approach (PLA). *, P<0.05 indicates statistical significance between the SuperPATH group and PLA groups

The angle of acetabular inclination was 47.04°±5.45°in the Super PATH group and 44.14°±3.13°in the PLA group;these differences were statistically significant (t=3.264,P = 0.02).The angle of acetabular anteversion were 23.42°±5.17°and 18.86°±4.72°for the Super PATH group and the conventional group with significant difference(t=4.603,P = 0.000).There were five patients (10.4%) in the Super PATH groups and one (2.1%) in the PLA group with LLD>1 cm. Although no statistically significant (p =0.215 , exact chi-squared test), the result was deemed to be clinically significant.

Discussion

Super PATH approach is considered a muscle-sparing approach, because except of a small incision of gluteus maximus, it takes advantage of the interval between gluteus medius and the piriformis to reach the superior hip joint capsule [6]. In complex cases or where access proves difficult, the incision may be extended into a standard posterolateral approach. In this study, we found that compared with the conventional PLA, the Super PATH approach for THA had some advantages, such as shorter incision, lower postoperative VAS, and better postoperative HHS at 1 and 3 months after surgery. However, Super PATH approach did not reduce surgical bleeding and shorten hospital stay and was associated with a significantly longer operative time.

One of the advantages of minimally invasive surgery is that it can reduce the injury of muscle and soft tissue. Super PATH approach was correlated with lower levels of inflammation markers comparing with standard approaches. A recent study in 2021 by Li et al found that both levels of CRP and CK were remarkably lower in the Super Path group compared with the conventional group at 3 d after surgery ($P < 0.05$), further suggesting the Super Path approach might facilitate the patients' recovery from postoperative inflammation [12]. However, a recent study demonstrated that the Super PATH approach unexpectedly yielded more soft tissue damage and significantly increased serum CK levels compared with the PLA on day 3 postoperatively [13]. In our study, no difference was found concerning the increase of serum CRP, CK and ESR levels between the two groups. These inconsistent results were possibly attributable to additional intraoperative soft tissue (mainly muscle) damage from many sources, including intraoperative stretching, unintentional detachment, and varied instrument retraction, during the significantly elongated time taken to perform the procedure. A cadaveric model study by Amanatullah et al showed that the piriformis-sparing posterior approach to the hip causes inadvertent damage to the piriformis muscle in $>90\%$ of cases and that this damage occurs outside of the surgical field [14]. Operative time usually increases in the learning curve for a new surgical approach [15, 16]. Super PATH technology were related to more operative time and blood loss than conventional approaches [17-19]. Due to insufficient exposure and limited visual field, it took more time to perform the operation. Lei et al [16] reported that the average operation time in the first 20 patients undergoing THA using the Super PATH approach was 122.65 ± 27.45 min, and the operative time continued to decrease, which dropped to 82.85 ± 5.44 in the third 20 cases and 79.00 ± 8.22 in the fourth 20 cases. A recent systematic analysis confirmed that the operative time of the Super PATH group was 18.4 min longer than the conventional approach group [7]. With the increase of operative time, the intraoperative blood loss will also increase. Mas et al [19] reported that the mean blood loss in the Super Path cohort was greater than posterior cohort (977.85 ± 285.1 ml VS 752.46 ± 299.3 ml), the differences were statistically significant. In our study, the mean operative time was 79.26 min, which was significantly higher than the PLA group. The increase of operative time was related to the following factors: insufficient surgical field of vision, the learning curve stage and intraoperative fluoroscopy. This fact might have played a role in the greater intraoperative bleeding in the Super PATH group, even though it is an approach that preserves the soft tissues better. Therefore, if the operative time is well controlled, the intraoperative blood loss will be greatly reduced.

Previous studies had confirmed that the VAS score were lower and HS was higher in the SuperPATH cohort comparing to the conventional approach in the early operative phase [20]. Our study also confirmed the same results. However, the meta-analysis by Ramadanov found that no differences in pain VAS between hip replacements via SuperPATH and conventional approaches 1, 3 days, 3 and 12 months postoperatively [7]. On the contrary, Meng et al [13] found that pain VAS was significantly higher in the SuperPath group (7.05) than the PLA group (6.55) on postoperative day 3 and remained comparable between both groups at other time points within 1 year postoperatively. The meta-analysis by Ramadanov reported that HS on 7 days postoperatively was 10.2 higher in hip replacement via SuperPATH approach compared to hip replacement via conventional approaches [7]. Meng et al. [13] reported that differences in average HHS were not significant between the PLA groups and SuperPATH groups at any time point, hip function was observed to be significantly improved on postoperative day 14 (70.66 ± 6.22) in the PLA group, but only showed a significant improvement at 3 months postoperatively (82.44 ± 3.51) in the SuperPath group. Their data indicated that SuperPATH was associated with overall inferior patient-reported outcomes during the early postoperative phase in terms of pain symptoms and hip function.

visualization of anatomical landmarks and alignment of the components more challenging in MIS-THA due to the constrained surgical field [21], which makes intraoperative complications including fracture and component misalignment more prevalent. Deficient acetabular cup positioning might increase the wear rate and deteriorate the long-term stability of the hip implants [22], which is also the main cause of postoperative dislocation [23, 24]. Implant malposition was one of considerable controversy for the minimally invasive technique due to poor exposure [25]. In the present study, we found a larger average inclination and anteversion angle in the SuperPATH group than in PLA group. A study by Tottas et al had revealed statistically significant larger average cup inclination and smaller cup anteversion in the SuperPATH group than in the Hardinge group [18]. However, previous studies had found no difference between SuperPATH approach and conventional approach neither in anteversion nor in inclination [7, 20].

Conversely, Meng W et al found that a significantly lower average abduction angle in the SuperPath group compared with the PLA group for hip OA [26]. In this study, the complications of SuperPATH group did not increase compared with the PLA group. The risk of postoperative dislocation in the SuperPATH approach is theoretically lower than traditional approach due to preserving the short external rotator muscle and joint capsule [27]. However, it is very interesting that there were still two cases of anterior dislocations (4.3%) in the Super PATH group, which was only single case of posterior dislocation (2.1%) in the PLA group. The two dislocations in the Super PATH group occurred within 2 hours after operation and successfully treated by closed reduction without anesthesia, which was related to excessive anteversion of acetabular prosthesis. LLD can occur following THA and is a common source of patient dissatisfaction and litigation [28]. In terms of LLD, Tottas et al confirmed that no significant differences were found between SuperPATH approach and standard modified Hardinge approach [18]. The higher rate of LLD associated with the piriformis-sparing approach may be attributable to the lack of visualisation of the lesser trochanter, which is often used as a reference point for femoral neck osteotomy [29]. This situation also exists in the Super PATH approach.

The present study also has some limitations. Firstly, the sample size of the study is relatively limited and the postoperative follow-up was short, long-term efficacy of the Super PATH are still needed to be observed. Secondly, different implants utilized for both approaches might have influenced on the postoperative outcomes, especially the long-term survival rate of prosthesis. Third, the extent of muscle damage was only assessed with serum markers within 2 weeks postoperatively, while no radiographic analyses, such as magnetic resonance imaging, were performed to confirm perioperative alterations of these serum markers.

In conclusion, we found Super PATH approach in THA had better postoperative recovery efficacy with better hip function and less pain than patients with conventional PLA. However, the Super PATH approach had a longer operative time and more blood loss and the long-term effect needs to be further observed.

Abbreviations

Supercapsular percutaneously-assisted total hip: Super PATH; PLA: posterolateral approach; LHS: length of hospital stay; ASA: American Society of Anesthesiologists Classification; BMI: Body mass index; CK: Creatine kinase; CRP: C-reactive protein; ESR: erythrocyte sedimentation rate; THA: Total hip arthroplasty; VAS: Visual analog scale; LLD: leg length discrepancy; VTD: venous thrombotic events

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Authors' contributions

FPG, and KQY contributed to the conception and design of the study. FPG was a major contributor for drafting the manuscript. FPG was the chief surgeon responsible for operation. QBZ, XXL, ZLX, and XL contributed to the acquisition of the data. FPG, QBZ contributed to the analysis and interpretation of the data. FPG, QBZ and XXL make important revisions. FPG contributed responsibly for the overall content as guarantors. All authors read and approved the final manuscript.

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Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

This study was approved by the Ethic Committee of Gui Gang city peoples Hosptial (approval number GYLLPJ-20210813-21).All the patients included in this study provided signed informed consent.

Consent for Publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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