

# Comparison The Early Clinical Efficacy of SuperPath Approach Versus The Modified Hardinge Approach In Total Hip Arthroplasty For Femoral Neck Fractures In Elderly: A Randomized Controlled Trial

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## Research Article

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## Abstract

**Purpose:** Femoral neck fracture is a common form of hip fracture in the elderly. Minimally invasive surgery is very popular in recent years. This study was to investigate the clinical efficacy and advantages of the SuperPath approach to total hip arthroplasty in the treatment of femoral neck fractures in the elderly.

**Methods:** From February 2018 to March 2019, 120 patients were random divided into two groups with 60 patients each: the SuperPath group and conventional group. The results evaluated the general operation situation, Serum markers, blood loss, pain score, hip function and prosthesis location analysis.

**Results:** There was no difference demographically between two groups. Compared with the conventional group, the SuperPath group had a shorter operation time (78.4 vs 93.0 min), smaller incision length (5.8 vs 12.5 cm), less intraoperative blood loss (121.5 vs 178.8 ml), shorter hospitalization time (8.0 vs 10.8 day) and less drainage volume (77.8 vs 141.2 ml). The creatine kinase (CK) in the SuperPath group was significantly lower, while there was no difference in the C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR). The visual analog scale (VAS) was lower in one month and Harris Hip Score (HHS) were higher in three months in the SuperPath group. There was no difference in the cup abduction angle and anteversion angle of the two groups.

**Conclusion:** We found the better clinical efficacy after the SuperPath approach with less muscle damage, less postoperative pain and better postoperative function compared with the modified Hardinge approach.

**Trial registration:** Retrospectively registered. The randomized clinical trial was retrospective registered at Chinese Clinical Trial Registry on December 31, 2020 (ChiCTR-2000041583, <http://www.chictr.org.cn/showproj.aspx?proj=57008>).

## Introduction

Femoral neck fracture is a common form of hip fracture in the elderly, and the mortality rate is as high as 25% in the first year after the fracture[1–3]. The most preferred treatment method for most femoral neck fractures is surgical treatment, and non-surgical treatment should only be selected when the patient has a serious disease or serious surgical risk[4, 5]. The operative options include multiple cancellous lag screws, open reduction and internal fixation, hemiarthroplasty and total hip arthroplasty (THA), and its main choice depends on factors such as fracture type, age, function and bone quality[6, 7]. Although hemiarthroplasty is the preferred treatment for femoral neck fractures in the elderly, the American Academy of Orthopaedic Surgeons (AAOS) recommends that THA should be appropriately substituted for hemiarthroplasty in patients with femoral neck fracture[8].

THA, one of the greatest advances in orthopedic surgery, can significantly improve the quality of life of patients with end-stage hip joint disease, increase function, restore range of joint movement, and relieve

pain[9, 10]. There are multiple surgical approaches for THA, including traditional posterior approach (PA), anterior approach (AA), lateral approach (LA) and modified Hardinge approach[11, 12]. These traditional surgical approaches have some common shortcomings of external trochanter muscle injury, postoperative dislocation and longer recovery time [13–15]. The ideal approach for THA should reach the surgical site completely through muscles, blood vessels, and nerve spaces and it has the advantages of less damage, less bleeding, less postoperative pain symptoms, and faster recovery, but there is currently no one way to achieve this ideal state[16–18]. In 2011, Dr. James Chow first reported the supercapsular percutaneously assisted total hip (SuperPath, MicroPort Orthopedics Inc., Arlington, TN) approach, which combines the advantages of the supercapsular (SuperCap, MicroPort Orthopedics Inc., Arlington, TN, USA) approach and the percutaneously assisted total hip (PATH, MicroPort Orthopedics Inc., Arlington, TN, USA ) approach[15]. The SuperPath technique reaches the hip joint capsule through the tissue gap between the gluteus medius and the piriformis, so this technique reduces need for cutting muscles and tendon to protect the external rotator muscle[19, 20]. Previously reported that SuperPath technology has shown that the time to go to the ground is shortened, the hospital stay is short, the incidence of complications is low, and the in-hospital cost is low[21, 22].

Some femoral neck fracture patients have been selected for THA using the SuperPath approach in our hospital since August 2016. In reviewing our first 45 consecutive SuperPath cases, we discovered that the operation time was longer and fluctuated significantly in the first 25 cases, while the operation time showed a clear downward trend in about 25 to 45 cases. This result is similar to the learning curve of the SuperPath approach previously reported in a retrospective clinical study by Rasuli et al[23]. The results showed that operative time in the SuperPath approach was still decreasing and proficiency continues to improve in the first 50 cases[23]. Although the SuperPath approach is getting more attention and application in the clinical, the clinical research on the SuperPath approach is still insufficient, so we compared the results of the SuperPath approach with other traditional approach (modified Hardinge approach) in a prospective cohort study. Before the prospective cohort study, we have basically mastered the SuperPath approach surgery technique, so this can better explore the advantages and disadvantages of this approach compared to other surgical approaches. The purpose of this study is to compare the clinical efficacy of SuperPath approach with the modified Hardinge approach in the treatment of femoral neck fractures and share some skills in SuperPath approach surgery.

## Materials And Methods

### Study design

This was a prospective randomized controlled trial of patients with femoral neck fracture. This research was approved by the Medical Ethics Committee of the Lishui People's Hospital, The Sixth Affiliated Hospital of Wenzhou Medical University, Lishui, China. The inclusion criteria were: (1) patients with fresh femoral neck fracture (type Garden III and IV); (2) the age of the patient was  $\geq 65$  years old; (3) the surgical approach was either the SuperPath minimally invasive approach to THA or the modified Hardinge approach to THA for femoral neck fractures; (4) ability to complete scheduled postoperative 12

months follow-ups. The exclusion criteria were: (1) patients with pathological fracture, femoral head necrosis, and arthritis of the affected hip joint; (2) the patients had hip joint disease, severe hip joint anatomical deformity, and hip joint dysfunction before fracture; (3) body mass index (BMI) > 30 kg/m<sup>2</sup>; (4) The follow-up time was less than 12 months.

## **Patients**

From January 2018 to April 2019, a total of 160 consecutive THA patients with femoral neck fracture were eligible in our hospital, of which 120 patients were enrolled and randomly divided into two groups in the study (Figure 1). After confirmation of eligibility, patients were randomized (1:1) to receive SuperPath or modified Hardinge approach of THA using the simple randomization method. The allocation sequence was computer-generated (<http://tools.medsci.cn/rand>). The study population consisted of 60 patients undergoing THA with SuperPath approach (SuperPath group) and 60 patients undergoing THA with the modified Hardinge approach (Conventional group). All operations were performed by a senior surgeon at our hospital. Surgical internal fixation implants: For the SuperPath group, the SuperPath total hip prosthesis system was provided by MicroPort Orthopedics Incorporated (USA). For the conventional group, the modified Hardinge total hip prosthesis system produced was provided by Biomet Orthopedics (USA).

## **Efficacy evaluation index**

All data were collected by a research fellow and a post-graduate student, not by the operating surgeon. One-year follow-up was the primary endpoint. The patient demographic characteristics were collected, including age, gender, side, body mass index, and American Society of Anesthesiologists (ASA) class. The following indicators were used to assess the functional outcome of the two groups. (1) General operation situation: operation time, intraoperative blood loss, incision length, hospitalization time and the occurrence of surgery-related complications; (2) Serum markers: inflammatory response indicators (C-reactive protein (CRP), erythrocyte sedimentation rate (ESR)) and muscle injury indicators (creatinine kinase (CK)). These serum markers were collected for each patient on the day of hospital admission, postoperative day 1, day 3, and day 7, respectively. (3) Blood loss: Hemoglobin (Hb) and Hematocrit (HCT) were collected for each patient on the day of hospital admission, postoperative day 1, and day 3, respectively. Drainage tubes were routinely placed in each patient, and the drainage tube was removed and the drainage volume was recorded on the first postoperative day. (4) Pain and hip function: visual analog scale (VAS) score was collected on the day of hospital admission, postoperative day 1, day 3, day 7, 1 month, 3 months, 6 months, and 12 months respectively. Harris Hip Score (HHS) was evaluated at postoperative one week, 1 month, 3 months, 6 months, and 12 months. (5) Component placement analysis: All postoperative anteroposterior pelvic radiographs were standardized with the patient in the supine position and the radiation beam focused at the pubic symphysis with a focal length of 100 cm. The abduction angle and anteversion angle were measured on anteroposterior pelvic radiographs according to the method described by Bachhal et al [24].

## **SuperPath approach surgical technique**

Step 1: Patient positioning. the patient is placed in the standard lateral decubitus position with the operative hip in a slightly adducted position, 45° - 60° flexion, and 20° - 30° internal rotation (Figure 2a).

Step 2: Surgical exposure: a skin incision is made from the tip of the trochanter to the trochanter 5–7 cm proximally in line with the femur (Figure 2b). Using electrocautery to incise subcutaneous fat and fascia of the gluteus maximus muscle. The gluteus maximus muscle is split by two wing-tipped elevator dissection in line with the fibers (Or using the index finger to separate the gluteus maximus, and can touch the posterior edge of the gluteus medius and the space between the piriformis and gluteus minimus), then expose the posterior edge of the gluteus medius muscle with a cobb elevator (Figure 2c). Separating the space between the gluteus minimus muscle and piriformis tendon to reach the hip joint capsule, then two blunt Hohmann retractors are inserted before and after the joint capsule (Figure 2d). The hip capsule is incised from the saddle of the femoral neck to 1 cm proximal to the acetabulum rim.

Step 3: Femoral preparation. The zenith of femoral canal is made with a sharp starter reamer at medial of femoral trochanter apex. A femoral orientation is inserted from the zenith to the femoral condyle to determine the direction of the medullary cavity (Figure 2e). A blunt metaphyseal reamer was then used to expand the proximal femoral opening in this same line. Using a round calcar punch to remove a small portion of the bone from the outside of the femoral head for slotting to ensure the anteversion angle of the femoral component (Figure 2f). With the ream and broach system used, the femoral metaphysis is reamed in order from small to large until resistance met with the isthmus of the femoral canal. The broach handle is then removed at the final size, leaving the broach in place to act as a femoral component trial. Raising the leg to the abduction position, the femoral neck osteotomy is performed using an oscillating saw at the top of the medullary cavity file. Two Schanz pins are driven into the femoral head and ligament is cut off using electrocautery, and then using these two Schanz pins to rotate and remove the femoral head completely. If the head is difficult to remove, a small part of bone from femoral head is gouged to facilitate removal.

Step 4: Acetabular preparation and placement. Two spiked Hohmann retractors and a Zelpi retractor are placed beneath the acetabular margin to clear the rest of the labrum and ensure the transverse acetabular ligament. According to the alignment handle and guide, 1 cm auxiliary incision is made located posterior edge of femur and the alignment handle is removed leaving the cannula in place. Using the acetabular file holder, hang the acetabular file into the acetabulum through the main incision and file the acetabulum in order of size. acetabular basket reamers are used to reamed through the main incision until an appropriately sized acetabular implant is decided. The chosen acetabular implant is placed and the position is determined by the three screw hole indicator lines on the mortar cup aligned with the mortar crest from 11 to 1 o'clock (Figure 2g). Screw drilling with a sleeve inside the cannula and insertion with a straight ratchet screwdriver is also achieved through the cannula when necessary (It is more difficult for a beginner to place screws. At this time, we recommend that the original drill of MicroPort be replaced to a 2.0 Kirschner wire for drilling, which will make the drilling easier. Before preparing to insert the screw, you

can touch the screw hole distribution position with your finger) (Figure 2h). Then lining is implanted. The trial head and neck are then brought together using a bone hook and a T-handle to gently manipulate the femur.

Step 5: Model trial: After trial reduction, flexion (100° - 120°), extension (5° - 10°), internal rotation (30° - 40°) and external rotation (30° - 40°) of the patient's limb is performed and C-arm fluoroscopy is used to test the stability of the trial implants.

Step 6: Implant assembly. The trial implants are replaced with definitive prosthesis and then stability is checked again:

Step 7: The wound is irrigated and checked for bleedings. The hip joint capsule is closed with a suture and a drainage tube is placed through the auxiliary incision. Finally, routine suture of gluteus maximus fascia, subcutaneous tissue and skin successively (Figure 2i).

### **Statistical analysis**

Values are expressed as the means  $\pm$  standard deviation (SD). Differences between the two groups were performed using the Independent sample t test, Fisher's exact test and the  $\chi^2$  test using SPSS (version6.0; SPSS Inc., Chicago, IL, USA). Statistical analysis was performed using GraphPad Prism. Values of  $P < 0.05$  were considered to be statistically significant.

## **Results**

All 120 patients successfully completed the operation and 3 patients were lost follow-up in the SuperPath group, while 4 patients were lost follow-up in the conventional group. The patient's demographic information is shown in Table 1. SuperPath group: 29 males and 28 females; aged 66 to 93 years, with an average age of 75 years; There were 32 cases of left hip and 25 cases of right hip; BMI 17.3–27.4 kg/m<sup>2</sup>, with an average of 21.5 kg/m<sup>2</sup>; The value of ASA is  $2.07 \pm 0.42$ . Conventional group: 26 males and 30 females; aged 65 to 90 years, with an average of 74 years; There were 29 cases of left hip and 27 cases of right hip; BMI 17.3–25.9 kg/m<sup>2</sup>, with an average of 21.7 kg/m<sup>2</sup>; The value of ASA is  $2.05 \pm 0.35$ . There were no statistically statistical differences in gender, age, fracture Side, BMI, and ASA between the two groups ( $P > 0.05$ ).

Table 1  
Preoperative characteristics of patients in two groups (Mean  $\pm$  SD)

Parameters	SuperPath	Conventional	<i>P</i> value
	group (n = 57)	group (n = 56)	
No. of patients	57	56	-
Age (years)	75.2 $\pm$ 6.4	74.4 $\pm$ 6.1	0.505
Gender(M/F)	29/28	26/30	0.640
Side (L/R)	32/25	29/27	0.518
BMI (kg/m <sup>2</sup> )	21.5 $\pm$ 2.2	21.7 $\pm$ 2.0	0.529
ASA (grade)	2.07 $\pm$ 0.42	2.05 $\pm$ 0.35	0.820

\**P*<0.05 indicate significant differences from the conventional. BMI, body mass index; ASA, American Society of Anesthesiologists.

Compared with the conventional group, the SuperPath group had shorter operation time, smaller incision length, less intraoperative blood loss, shorter hospitalization time and less drainage volume (*P*<0.05). There was no significant difference in postoperative blood transfusion rate between the two groups (*P*>0.05) (Table 2). There was no significant difference in CRP and ESR between the two groups at the day of hospital admission, postoperative day 1, day 3, and day 7 (*P*>0.05). Compared with the conventional group, the CK in the SuperPath group was significantly lower than the CK in the conventional group at the postoperative day 1, day 3, and day 7 (*P*<0.05) (Table 3, Fig. 3). There was no significant difference in Hb and HCT between the two groups at the day of hospital admission, postoperative day 1, day 3, and day 7 (*P*>0.05) (Table 4, Fig. 4). The trends of HHS and VAS score in two groups were showed in Fig. 5. There was no statistically significant difference in VAS scores of the two groups on the day of hospital admission (*P*>0.05). The VAS scores in the SuperPath group at 1-, 3-, 7-day and 1-month follow-up intervals were significantly lower than the VAS scores in the conventional group, but not significantly different at 3-, 6- and 12-month follow-up intervals (Table 5). The HHS in the SuperPath group were significantly higher than those in the conventional group at 7-day, 1- and 3-month follow-up intervals, but not significantly different at 6- and 12-month follow-up intervals (Table 5). There is no statistical difference between the cup abduction angle and anteversion angle of the two groups, and they are all within the Lewinnek's safe zone[25] (Table 6). None of the patients had prosthesis dislocation, proximal femoral fractures, postoperative infection, nerve damage, or heterotopic ossification in two groups.

Table 2  
Perioperative general operation situation in two groups (Mean  $\pm$  SD)

Parameters	SuperPath	Conventional	<i>P</i> value
	group (n = 57)	group (n = 56)	
Operation time (min)	78.3 $\pm$ 8.0	93.6 $\pm$ 10.9	0.000*
intraoperative blood loss (ml)	122.3 $\pm$ 30.1	178.2 $\pm$ 31.6	0.000*
Incision length (cm)	5.8 $\pm$ 0.4	12.5 $\pm$ 0.8	0.000*
hospitalization time (days)	8.1 $\pm$ 1.3	10.8 $\pm$ 1.4	0.000*
drainage volume (ml)	77.8 $\pm$ 48.1	137.2 $\pm$ 57.0	0.000*
Transfusion rate	2/57	3/56	0.636

\**P*< 0.05 indicate significant differences from the conventional.

Table 3  
Perioperative serum markers change in two groups (Mean  $\pm$  SD)

Parameters	Timings	SuperPath	Conventional	<i>P</i> value
		group (n = 57)	group (n = 56)	
CRP	pre	7.39 $\pm$ 6.55	7.16 $\pm$ 6.27	0.848
	1 d	62.72 $\pm$ 25.83	64.10 $\pm$ 21.27	0.757
	3 d	62.34 $\pm$ 20.58	58.31 $\pm$ 26.81	0.371
	7 d	14.45 $\pm$ 9.63	16.33 $\pm$ 10.51	0.323
ESR	pre	18.04 $\pm$ 5.75	17.68 $\pm$ 4.94	0.725
	1 d	29.60 $\pm$ 6.72	27.63 $\pm$ 6.61	0.119
	3 d	50.16 $\pm$ 14.61	52.18 $\pm$ 15.07	0.471
	7 d	29.19 $\pm$ 10.06	30.52 $\pm$ 10.45	0.494
CK	pre	80.70 $\pm$ 43.90	84.70 $\pm$ 49.30	0.650
	1 d	279.58 $\pm$ 88.67	609.71 $\pm$ 111.31	0.000*
	3 d	168.54 $\pm$ 85.61	314.02 $\pm$ 123.19	0.000*
	7 d	89.95 $\pm$ 50.90	119.14 $\pm$ 59.27	0.006*

\**P*< 0.05 indicate significant differences from the conventional. CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; CK, creatine kinase.

Table 4  
Perioperative hemoglobin and hematocrit change in two groups (Mean  $\pm$  SD)

Parameters	Timings	SuperPath	Conventional	<i>P</i> value
		group (n = 57)	group (n = 56)	
Hb (g/L)	pre	122.2 $\pm$ 17.4	124.7 $\pm$ 14.8	0.415
	1 d	98.5 $\pm$ 12.0	97.3 $\pm$ 12.7	0.615
	3 d	96.4 $\pm$ 10.9	94.6 $\pm$ 12.3	0.423
HCT (%)	pre	36.4 $\pm$ 5.3	37.2 $\pm$ 4.2	0.369
	1 d	29.4 $\pm$ 3.8	29.8 $\pm$ 4.2	0.548
	3 d	28.2 $\pm$ 3.5	28.3 $\pm$ 3.4	0.865

\**P*<0.05 indicate significant differences from the conventional. Hb, Hemoglobin; HCT, hematocrit.

Table 5  
Pain and hip function in two groups (Mean  $\pm$  SD)

Parameters	Timings	SuperPath	Conventional	<i>P</i> value
		group (n = 57)	group (n = 56)	
VAS	pre	7.19 $\pm$ 0.72	7.16 $\pm$ 0.66	0.803
	1 d	5.89 $\pm$ 0.72	6.46 $\pm$ 0.95	0.001*
	3 d	5.12 $\pm$ 0.71	5.89 $\pm$ 0.73	0.000*
	7 d	4.47 $\pm$ 0.68	4.84 $\pm$ 0.73	0.007*
	1 m	1.93 $\pm$ 0.53	2.34 $\pm$ 0.55	0.000*
	3 m	1.11 $\pm$ 0.67	1.20 $\pm$ 0.62	0.454
	6 m	0.91 $\pm$ 0.71	0.89 $\pm$ 0.68	0.883
	12 m	0.72 $\pm$ 0.65	0.69 $\pm$ 0.63	0.850
HHS	7 d	74.41 $\pm$ 3.10	69.41 $\pm$ 3.38	0.000*
	1 m	84.19 $\pm$ 3.08	79.48 $\pm$ 3.10	0.000*
	3 m	89.90 $\pm$ 2.33	86.25 $\pm$ 3.04	0.000*
	6 m	90.68 $\pm$ 1.59	90.75 $\pm$ 2.41	0.868
	12 m	91.72 $\pm$ 1.20	91.67 $\pm$ 0.94	0.800

\**P*<0.05 indicate significant differences from the conventional. VAS, visual analog scale; HHS, Harris Hip Score.

Table 6  
Radiologic evaluation of the acetabular cup positioning in two groups (Mean  $\pm$  SD)

Parameters	SuperPath	Conventional	P value
	group (n = 57)	group (n = 56)	
Abduction angle (degrees)	43.81 $\pm$ 3.08	42.80 $\pm$ 3.62	0.131
Anteversion angle (degrees)	14.76 $\pm$ 3.26	14.10 $\pm$ 2.97	0.262

\*P< 0.05 indicate significant differences from the conventional.

## Discussion

This study found that, compared with the modified Hardinge approach, SuperPath approach has shorter operation time, shorter surgical incisions, less muscle damage, less postoperative pain, earlier discharge from hospital and better postoperative function. However, there was no significant difference between the two surgical approaches in terms of blood transfusion rate, postoperative complications, abduction angle, anteversion angle, and long-term function.

Our research results showed the operation time was  $78.3 \pm 8.0$  min in the SuperPath group and  $93.6 \pm 10.9$  min in the conventional group, there was a significant difference between the two groups. one reason may explain that the surgical incision exposure was more cumbersome and was stitching time in modified Hardinge approach. Some previous studies comparing the operation time of SuperPath approach with conventional posterior approach, the results were not consistent. Jia et al compared the SuperPath approach (50 cases) with the conventional posterior approach (50 cases) in hemiarthroplasty for senile femoral neck fractures, the results showed that the operation time of SuperPath approach ( $56 \pm 7$  min) was not significantly different from that of traditional posterolateral approach ( $53 \pm 6$  min)[26]. Wang et al compared the SuperPath approach (55 cases) with the conventional posterior approach (55 cases) in THA for femoral neck fractures in the elderly, the results showed that the operation time of SuperPath approach ( $108.6 \pm 15.9$  min) was not significantly different from that of traditional posterolateral approach ( $102.5 \pm 19.6$  min)[27]. Xie et al compared the SuperPath approach (46 cases) with the conventional posterior approach (46 cases) in THA for primary hip osteoarthritis, the results showed that the operation time of SuperPath approach ( $103.4 \pm 11.8$  min) was also not significantly different from that of traditional posterolateral approach ( $106.5 \pm 16.5$  min)[28]. However, Meng et al compared the SuperPath approach (4 cases) and the posterolateral approach (4 cases) in THA in bilateral osteonecrosis of the femoral head, the results showed that the operation time of SuperPath approach ( $103.3 \pm 12.4$  min) was significantly longer than that of traditional posterolateral approach ( $66.5 \pm 13.8$  min)[29]. The mean operation time of SuperPath approach in these studies was approximately 100 min, which was considerably longer than the average operation time in our study. We think that the reason for this difference may be due to the fact that we have already completed 50 cases of SuperPath learning during the comparative study. We better believe that the operation time of the

SuperPath approach is no longer than the operation of the conventional approach when the learning curve of the SuperPath approach is reaching a steady plateau. Noteworthily, the average incision length in SuperPath group in our study was  $5.8 \pm 0.4$  cm, which was not within the range of 6–8 cm incision lengths previously reported[19]. The reason why may be the BMI of Chinese is generally lower than that of foreigners. When there is more fat tissue or more muscle in the hip, a longer surgical incision is needed to expose the surgical field. Except from the benefits to the patient, surgery should also facilitate the surgeon's operation.

Serum markers, mainly CRP, ESR and CK, are widely used to evaluate soft tissue damage in the THA [30–32]. The results showed that the level of CK at different time points in the SuperPath group was obviously lower than that in the conventional group, which confirmed that the SuperPath approach for THA had less muscle damage and less trauma inflammation. The SuperPath approach retains the muscles around the hip joint such as the external rotation muscle group, piriformis muscle, gluteus minor muscle, and gluteus medius muscle, ensuring the integrity of the front and rear of the hip capsule[33]. The surgery uses in situ resection of the femoral neck and femoral head instead of dislocation of the hip joint, so it has the characteristics of less trauma and high safety[20]. Meng et al. prospectively analyzed the level of CK and inflammation after THA in SuperPath approach, and found that the levels of all serum markers in the SuperPath group were still relatively higher than those in the PLA group at all times[29]. Although the author believes that the SuperPath approach is a muscle gap approach, the elongated operation time and minimally invasive surgical operation have obvious effects on the stretching and contusion of the buttocks muscles, which is more likely to lead to increased serum markers. However, the most cases in our study were reached the SuperPath approach learning curve stage, and there was less tension and blunt injury to the gluteus maximus and gluteus medius during operation, so the level of CK was significance lower than the conventional group.

The total blood loss (TBL) of THA consists of the visible blood loss (VBL) of the intraoperative blood loss and the postoperative drainage, and the hidden blood loss (HBL) in the tissue[34–36]. In our experiment, the intraoperative blood loss, postoperative drainage volume, HB and HCT were selected to compare in two groups. Ours results have shown that there was no significant difference in HB and HCT between the two groups at all times, while the intraoperative blood loss and the postoperative drainage was different in two groups. We believe the reason for the lower VBL in the SuperPath group is less muscle damage. Although HBL was not specific calculated, we collected the changes of HB and HCT and inferred that the HBL of the two groups were similar. In a recent retrospective study, the HBL of the SuperPath group was significantly higher than that of the Moore group, but there was no significant difference in TBL between the two groups[37]. The author believes that the reason for the more HBL in SuperPath group is because the trabecular expansion procedure destroys the trabecular structure to increase the intramedullary hemorrhage of the femur and the inadequate hemostasis caused by the less visualization of the surgical field. We believe that after mastering the SuperPath approach, the above two reasons can be properly avoided. Therefore, more prospective randomized controlled trials are needed to more appropriately evaluate HBL of SuperPath approach.

In the context of accelerated rehabilitation, minimally invasive total hip arthroplasty, including SuperPath approach in THA, have received increasing attention from joint surgeons[38]. The great advantages of SuperPath approach are early recovery of joint function, shortening postoperative hospital stay and promoting rehabilitation[39]. Our results showed that compared with the modified Hardinge approach, the SuperPath approach had a lower VAS score for early pain after THA, shorter postoperative hospital stay, and faster early functional recovery. One reason explanation of mild postoperative pain symptoms in the SuperPath approach might be that SuperPath approach is performed through the muscle gap and the lower limb stretch and twist operations are gentler, which created conditions for early rapid recovery of patients. A study by Xie et al[28]. showed that the VAS score and HHS of the SuperPath group were significantly lower than those of the posterolateral approach group at 1-week, 1- and 3- month follow-up intervals. Jia et al[26]. also showed that the VAS score, HHS and Barthel Index in the SuperPath approach group at 1-week follow-up intervals were significantly lower than the posterolateral approach group, but not significantly different at 3-month and 2-year follow-up intervals. The above research results suggest that SuperPath approach for THA is conducive to early functional rehabilitation of patients, but the long-term results need to be confirmed by further studies.

A long-standing principle regarding the position of the components is that the cup abduction angle and anteversion angle are  $30^\circ - 50^\circ$  and  $5^\circ - 25^\circ$ , respectively[40]. Thus aiming to achieve a combined anteversion of  $25^\circ$  to  $45^\circ$ , with a range between  $25^\circ$  to  $35^\circ$  for men and  $30^\circ$  to  $45^\circ$  for women, which represent a “safe zone” defined by Lewinnek to minimizes dislocation after primary THA[25]. In the SuperPath group, the abduction angle and anteversion angle were  $43.85^\circ \pm 3.01^\circ$  and  $14.76^\circ \pm 3.26^\circ$ , respectively, which were not significantly different from the traditional group in our study. One reason can explain that SuperPath approach involves reaming and using in situ resection of the femoral neck and femoral head instead of dislocation of the hip joint. This allows precise measurement of the patient's anteversion and abduction. Recently, Della et al[38] demonstrated that the cup abduction angle and anteversion angle were safe in the SuperPath approach for THA, and this was confirmed by the study of Xie et al[28] in this issue of the Journal of orthopaedic surgery and research. These authors believe that such consistency in implant positioning may be the result of a lack of external soft-tissue forces during preparation and implantation and the SuperPath approach using a lateral position. Recent studies have pointed out that the Lewinnek “safe zone” does not really represent a safe area, and there is still a risk of dislocation in this area[40–43]. They point out the ideal cup location for some patients may be outside the Lewinnek safe zone and more advanced analysis is needed to determine the correct target in this subgroup[40, 44]. Considering the functional safe zone defined by Tezuka et al[43], we also routinely performed flexion ( $100^\circ - 120^\circ$ ), extension ( $5^\circ - 10^\circ$ ), internal rotation ( $30^\circ - 40^\circ$ ) and external rotation ( $30^\circ - 40^\circ$ ) of the patient's limbs after inserting the prosthesis to better evaluate the safety of the prosthesis.

Although the accurate learning curve of the SuperPath technique was not determined, we believe that the learning curve would be stabilized by case 50 for the SuperPath technique according to our clinical observations and the previous study by Rasuli et al[23]. A previous study describing outcome characteristics for the SuperPath approach showed that the rate of prosthesis dislocation was 0.8%, deep

vein thrombosis 0.2% and periprosthetic fracture 0.8%[22]. Therefore, we believe that the SuperPath surgery is safe and useful. As the number of operations gradually increasing, the surgeon's experience is constantly enriched and the incidence of complications will also be reduced.

The several limitations of this study include short follow-up time and not enough cases, and the long-term clinical efficacy of SuperPath approach for THA needs further observation. In addition, the psychological suggestion of patients in the SuperPath group may have an impact on the postoperative pain of VAS score and postoperative rehabilitation exercise. Previous study demonstrated that BMI may affect the exposure of surgical incisions and postoperative incision infections[31]. In this study, we only included patients with BMI less than 30, so our results may be relatively limited. Since the control group did not choose other minimally invasive surgical methods, it may be easy to exaggerate the characteristics of the SuperPath approach for THA. Considering this problem and combining our research results, we will compare the SuperPath approach with the direct anterior approach in the follow-up work, which may better reflect the SuperPath approach and provide further value for the clinic.

We believe that the SuperPath approach for THA attracts surgeons to choose this approach has these aspects: First, The SuperPath approach reaches the surgical site completely through muscles gap, which has the advantages of less damage, less bleeding, less postoperative pain symptoms, and faster recovery. These points have been confirmed in recent articles and our research. Second, the SuperPath surgery requires many special instruments and the incision is not completely exposed which is the restrictive reason for SuperPath approach promotion, while with the accumulation of experience and the improvement of surgical cooperation, the surgical approach will become more mature, accurate and safe. In addition, the SuperPath approach has many similar steps to the traditional posterolateral approach, so the learning process for orthopedics may be shorter than other minimally invasive approaches. Third, compared with direct anterior approach, the SuperPath approach may be less prone to fracture of the proximal femur because there is no leverage in the process of in-situ femoral bone marrow cavity preparation and femoral neck amputation in elderly patients with severe osteoporosis. This point needs to be proven by subsequent clinical studies.

## Conclusions

In summary, the data from this study clearly illustrate that superiority of the SuperPath approach in patients with femoral neck fractures. Compared with the conventional group, SuperPath group has shorter operation time, shorter surgical incisions, less muscle damage, less postoperative pain, earlier discharge from hospital and better postoperative function. In addition, more randomized controlled trials and long-term follow-up observation are needed to further prove the advantages and disadvantages of the SuperPath approach.

## Declarations

### Ethics approval and consent to participate

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The trial was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Research Ethics Boards of the Lishui People's Hospital, The Sixth Affiliated Hospital of Wenzhou Medical University (2017-96). The randomized clinical trial was retrospective registered at Chinese Clinical Trial Registry on December 31, 2020 (ChiCTR-2000041583, <http://www.chictr.org.cn/showproj.aspx?proj=57008>). All participants provided written informed consent before enrollment.

### **Consent for publication**

Not applicable.

### **Availability of data and materials**

All data generated or analysed during this study are included in this published article.

### **Competing interests**

The authors declare that they have no competing interests.

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### **Authors' contributions**

WPJ and BW contribute to conceptualization and methodology. JQS, YBL and SJH perform formal analysis and investigation. JQS was a major contributor in writing the manuscript. Writing - review and editing was done by WPJ, ZJY and HYS. The study was supervised by BW, HYS and WPJ. All authors read and approved the final manuscript.

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Not applicable.

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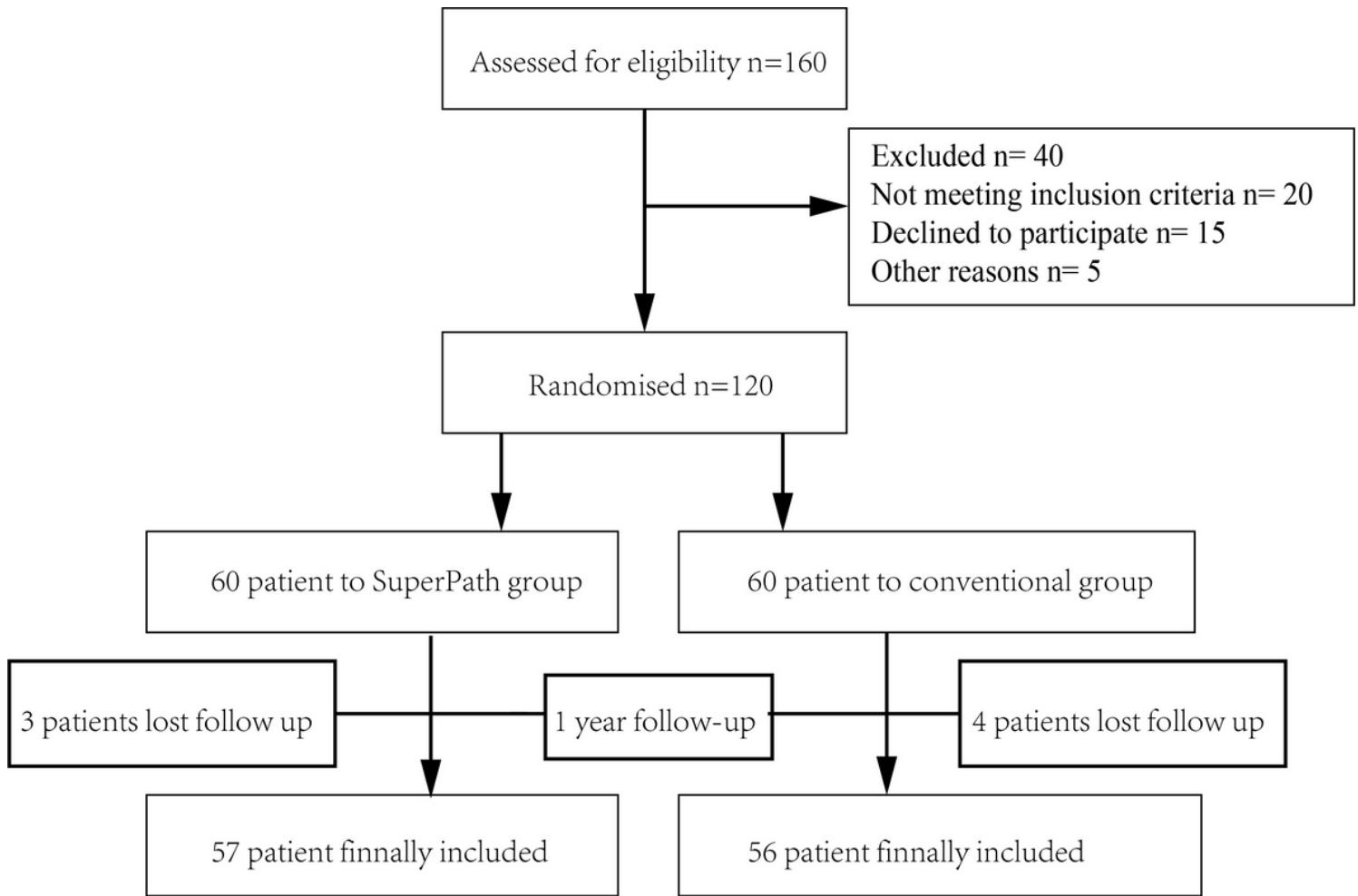
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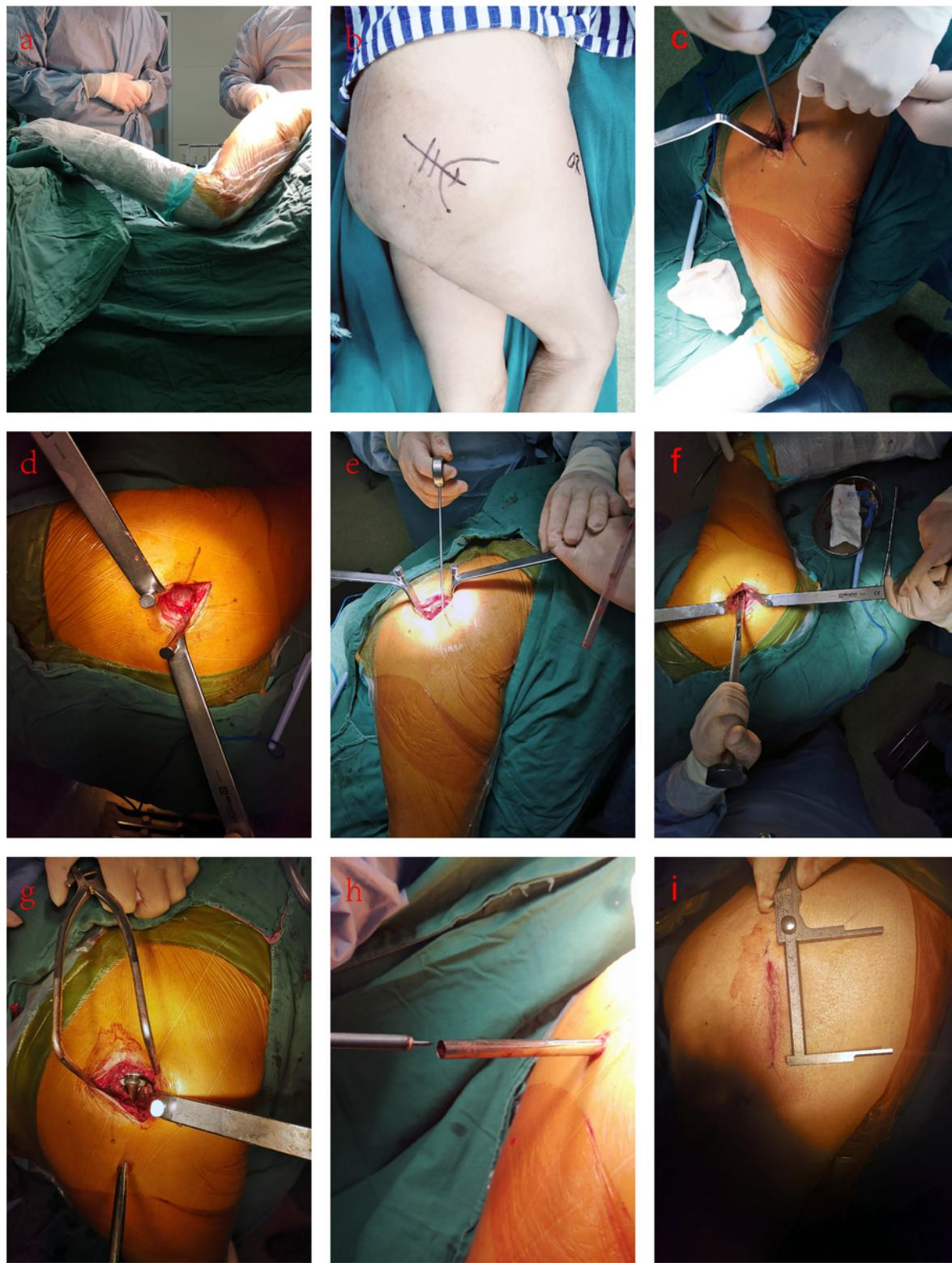
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## Figures



**Figure 1**

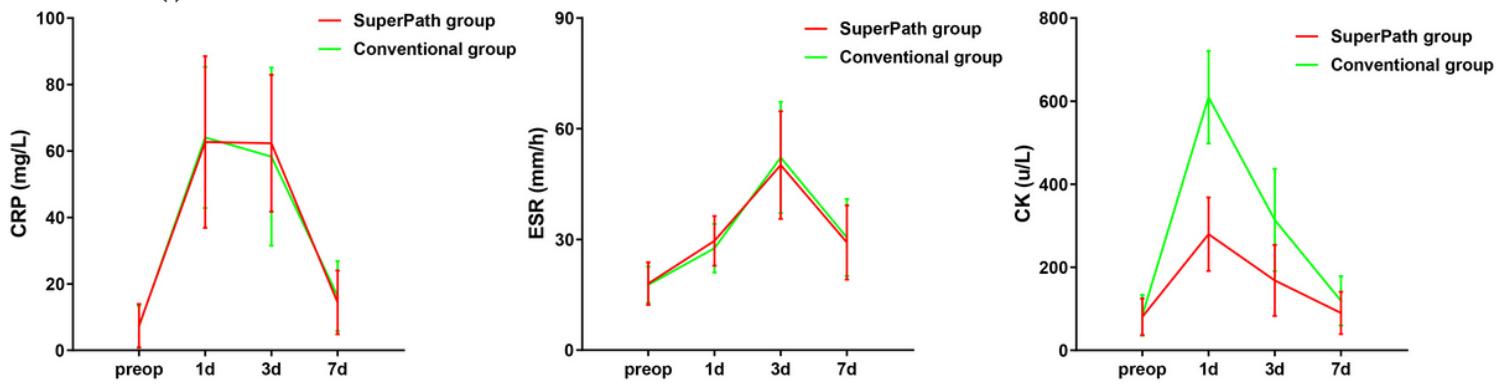
Flow diagram of the progress through the phases of the randomized trial.



**Figure 2**

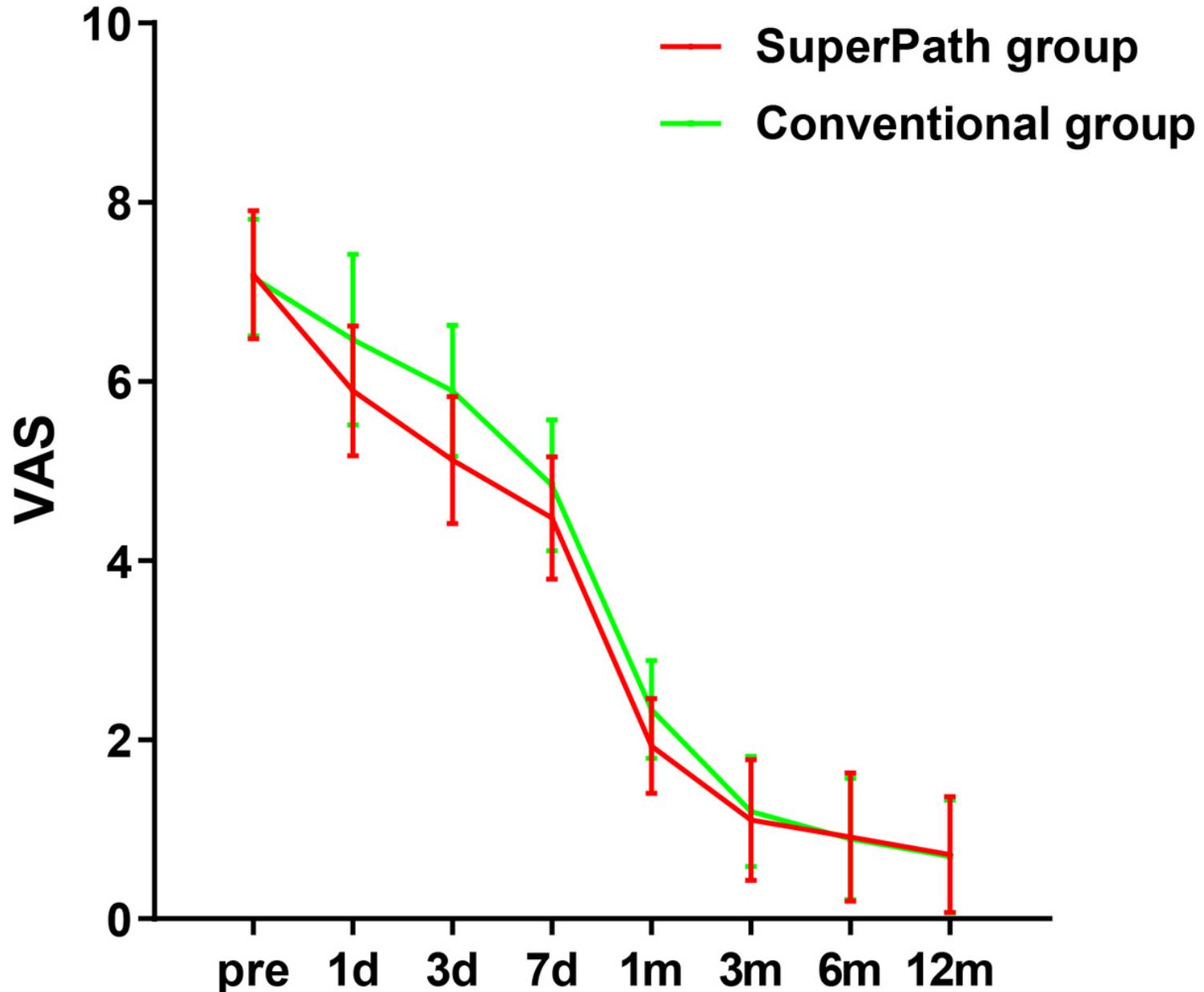
The SuperPath approach for total hip arthroplasty (THA) in femoral neck fractures: (a) Patient positioning; (b) Skin incision; (c) Split the gluteus maximus muscle and expose the posterior edge of the gluteus medius muscle; (d) Two blunt Hohmann retractors are inserted before and after the joint capsule; (e) Determine the direction of the medullary cavity; (f) Create the initial canal and ensure the anteversion

angle of the femoral component; (g) Place the acetabular implant and determine the position; (h) Insert the screw; (i) Close the incision.



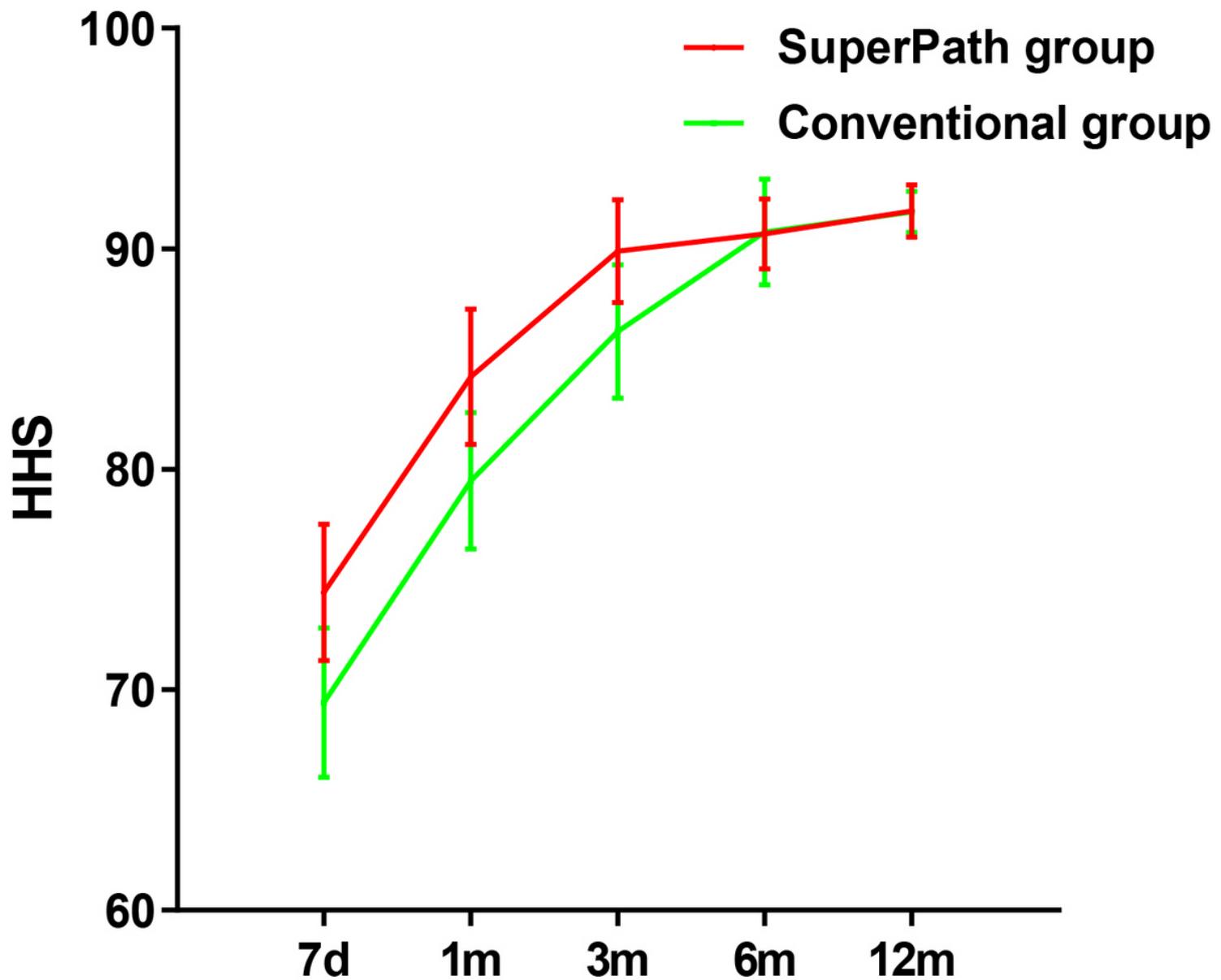
**Figure 3**

Pre- and postoperative levels of Serum markers in the SuperPath and conventional groups.



**Figure 4**

Pre- and postoperative visual analog scale (VAS) in the SuperPath and conventional groups.



**Figure 5**

Pre- and postoperative Harris Hip Score (HHS) in the SuperPath and conventional groups.