



Posterior Approach and Inferior Capsulotomy in Bipolar Hemiarthroplasty for Femoral Neck Fractures: Comparison with Superior Capsulotomy

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Background: Hemiarthroplasty is frequently used to treat displaced femoral neck fractures in elderly patients, but it has a higher risk of postoperative dislocation. We introduced the posterior approach and inferior capsulotomy (PAICO) to enhance joint stability after bipolar hemiarthroplasty for femoral neck fracture. We evaluated whether the PAICO would have a lower dislocation rate than the conventional posterior approach with superior capsulotomy.

Methods: From January 2021 to December 2021, we prospectively recruited 25 patients (25 hips) aged 50 years or older who underwent bipolar hemiarthroplasty for femoral neck fractures due to low-energy trauma as the PAICO group. We compared the PAICO group with a historical control group who had undergone hemiarthroplasty in 7 institutes between 2010 and 2020. The primary endpoint was dislocation within 1 year after the surgery. We compared data from the PAICO group with the data from the historical control group from the Korean Hip Fracture Registry which was carried out in South Korea.

Results: A total of 25 patients (25 hips) were enrolled in the present study; 3,477 patients (3,571 hips) who underwent bipolar hemiarthroplasty were reviewed as the historical control group. In the PAICO group, we observed no dislocation, whereas the dislocation rate in the control group was 1.3%.

Conclusions: In patients with displaced femoral neck fractures, the PAICO approach demonstrated comparable results in operation time and complication rates when compared to bipolar hemiarthroplasty using superior capsulotomy. Notably, there were no observed cases of dislocation among patients who underwent the PAICO approach. We recommend this PAICO approach to surgeons using the posterior approach, hoping to prevent dislocation in bipolar hemiarthroplasty.

Keywords: *Surgical procedure, Posterior capsulotomy, Hemiarthroplasty, Hip dislocation*

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Femoral neck fracture is one of the most common fractures in the elderly population.¹⁾ The displaced femoral neck fracture is associated with an increased risk of femoral head necrosis due to a disrupted blood flow, delayed union or nonunion, and failure of internal fixation. For this reason, displaced femoral neck fractures in older patients are often treated with hemiarthroplasty.²⁻⁴⁾ Hemiarthroplasty enables early mobilization, which is desirable in elderly patients because prolonged immobilization is associated with higher morbidity, mortality, and increased healthcare costs.⁵⁻⁸⁾

The results of hemiarthroplasty are known to be related to the surgical approach.⁹⁻¹¹⁾ Hip arthroplasties are most typically performed using posterior, direct lateral, anterolateral, and direct anterior approaches. The most common approach, the posterior approach, is technically simpler than other approaches, but is associated with a higher risk of postoperative dislocation.¹¹⁻¹⁵⁾

Traditionally, the posterior approach in hip arthroplasty is performed by cutting short external rotators, posterior capsulotomy, and posterior dislocation. The postoperative dislocation, therefore, typically occurs in posterior and superior directions when the hip is adducted, flexed, and internally rotated.¹¹⁾ It is reported that repair of posterior soft tissue plays a crucial role in reducing dislocation rate.^{11,12,16-19)} Results of the prior studies implied the dislocation rate would be even lower with an intact posterior capsule. Therefore, we began conducting inferior capsulotomy in the posterior approach to reduce the dislocation rate after bipolar hemiarthroplasty for patients with femoral neck fractures.

The aim of this study was to evaluate the clinical outcomes of bipolar hemiarthroplasty using the posterior approach and inferior capsulotomy (PAICO) and to determine whether shifting the site of capsulotomy (inferior vs. superior) altered the operation time and complication rates, including the dislocation rate, in patients undergoing bipolar hemiarthroplasty.

METHODS

The design and protocol of this prospective study were approved by the Institutional Review Board at Seoul National University Bundang Hospital, and all patients who were enrolled in the prospective cohort provided informed consent preoperatively (IRB No. B-2012-652-306). The study was registered in the ClinicalTrials.gov Protocol Registration System (trial no. NCT04719936).

Study Design

This is a prospective, single-center, open-label, non-randomized study with a historical control group.

PAICO Group

From January 2021 to December 2021, 25 consecutive patients (25 hips) underwent bipolar hemiarthroplasty with PAICO in a single tertiary medical institution. Inclusion criteria were patients with displaced femoral neck fractures resulting from low-energy trauma, who were aged 50 years or older. A fall was defined as a drop down from standing height or less. Exclusion criteria included high-energy trauma, metabolic bone disease such as Paget's disease, and pathologic fractures.

Historical Control Group

For the historical control group, we referred to the results from a retrospective cohort involving 7 institutes and 5,412 patients who underwent bipolar hemiarthroplasty with the posterior approach and superior capsulotomy at 7 centers from 2010 to 2020. Of those, 3,743 patients (3,855 hips) had the surgery due to the femoral neck fracture. This group's inclusion and exclusion standards were the same as those of the PAICO group. The mean follow-up period was 15.1 months (range, 12.2–25.6 months) (Table 1).

We chose this cohort because 7 surgeons in 7 hospitals had 1 year's experience of fellowship training in the same tertiary teaching hospital at different periods. After then, each surgeon performed annually at least 100 THAs and bipolar hemiarthroplasties using the conventional posterolateral approach in each hospital. Their data can be reliable and representative for the conventional posterolateral approach with superior capsulotomy.

Surgeons have similar surgical volumes and degrees of experience performing 100 to 200 surgeries due to hip

Table 1. Demographics of the PAICO Group and the Historical Control Group

Variable	PAICO group (n = 25)	Control group (n = 3,477)	p-value
Sex			0.57
Male	8 (32)	956 (27.5)	
Female	17 (68)	2,521 (72.5)	
Age (yr)	80.8 ± 9.6	79.4 ± 8.0	0.40
BMI (kg/m ²)	22.3 ± 3.8	21.7 ± 3.5	0.44

Values are presented as number (%) or mean ± standard deviation. PAICO: posterior approach and inferior capsulotomy, BMI: body mass index.

fractures per year. Various modern prostheses were used according to surgeons' preference. Surgeon expertise and surgical approach did not change during the study period from 2010 to 2020.

Demographics

There were 25 patients in the PAICO group and 3,743 patients in the historical control group with superior capsulotomy. In the control group, 205 patients died and 63 patients did not attend the hospital at least 1 year following the operation. No subsequent losses occurred in the PAICO group. Thus, 25 patients (25 hips) of the PAICO group (no one had bilateral surgeries) and 3,477 patients (3,571 hips) of the historical control group (94 patients had bilateral surgeries) were included in the final analysis.

Prosthesis

All operations in the PAICO group were performed by 1 surgeon (YKL) using a single cementless prosthesis design. All operation in the historical control groups were performed by 7 surgeons using a several modern prostheses.

In the PAICO group, the femoral component was a slightly tapered, rectangular, collarless titanium stem (Bencox M stem, Corentec). The proximal one-third of the stem was coated with plasma spray. A 28-mm alumina femoral head (BIOLOX forte, CeramTec AG, Plochingen) was used in all patients. The outer diameter of the bipolar cup ranged from 39 mm to 54 mm (46.1 ± 3.7 mm). In the historical control group, a variety of stems were used based on the surgeons' preferences (Supplementary Table 1). A

22-mm cobalt-chromium head was used in small-sized acetabulum. The outer diameter of the bipolar cup ranged from 39 mm to 60 mm (46.1 ± 3.16 mm).

Surgical Technique for Posterior Approach

For the posterior approach, we used the technique described by Langenbeck.²⁰⁾ The patient was placed on the lateral decubitus position and the hip was flexed by 30°. A straight skin incision was made over the center of the greater trochanter, equidistant cephalad, and caudad to the center of the trochanter. The length of skin incision ranged from 12 cm to 18 cm. The fascia lata was incised between the muscle bellies of the tensor fascia lata and the gluteus maximus. The trochanteric bursa was incised, and fat tissue overlying short external rotators was gently removed with a gauze to identify the posterior borders of the gluteus medius and the short external rotators. Short external rotators were detached with electrocautery as close as possible from their trochanteric insertion. After reflecting these muscles, the posterior capsule was exposed along the base of the neck. Using electrocautery, the capsule was incised from the piriformis fossa to the upper portion of the lesser trochanter along the base of the neck. For both approaches, the joint capsule was opened with a T-incision. Vertical capsulotomy was made along the axis of the femoral neck. Conventionally, capsulotomy was made at the level of the upper border of the femoral neck (superior capsulotomy) (Fig. 1). In the PAICO group, the capsulotomy was located at the level of the lower border of the femoral neck (inferior capsulotomy) (Fig. 2).

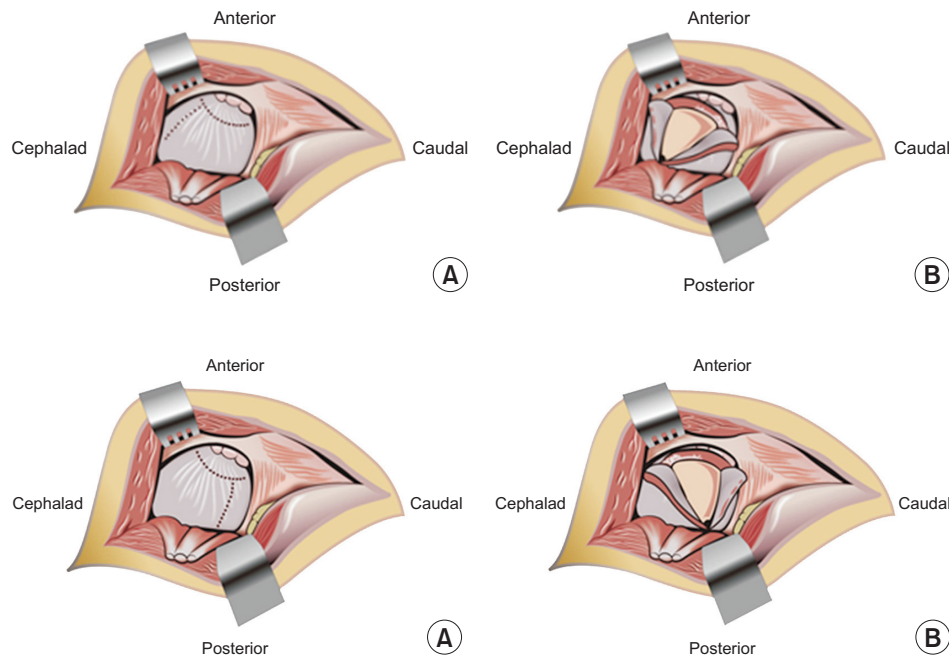


Fig. 1. (A) The capsulotomy was made at the level of the upper border of femoral neck. (B) Femoral head and neck were exposed after capsulotomy.

Fig. 2. (A) The capsulotomy was made at the level of the lower border of femoral neck. (B) Femoral head and neck were exposed after capsulotomy.

A trapezoidal posteriorly broad-based capsular flap was created. The femoral head was removed posteriorly from the acetabulum using a corkscrew, which was placed centrally in the head and twisted in. After implantation of the prosthesis, the joint capsule and short external rotators were repaired with sutures using the technique described by Ji et al.¹¹⁾ Absorbable mattress sutures were passed through the superior and inferior margins of the capsular flap, and then the capsular flap was reflected in 1 piece. The posterior capsular flap and the short rotators were reinserted to the posterior trochanteric edge, using either tendon-to-tendon sutures or tendon-to-bone sutures. Except for the location of capsulotomy, all surgical procedures including repair were done in the same manner. Patients were instructed to walk with partial weight-bearing with the aid of 2 crutches or walkers for 4 to 6 weeks after surgery.

Follow-up Evaluations

Routine follow-up visits were scheduled for 6 weeks, 3, 6, 9, 12, and 12 months after surgery. Twenty-five patients (25 hips) with PAICO and 3,477 patients (3,571 hips) with superior capsulotomy were compared with respect to sex, age, height, weight, body mass index (BMI), type of anesthesia and American Society of Anesthesiologists score, operation time, perioperative complications, length of hospital stay, and dislocation rate within 1 year.

Sample Size Calculation

Our null hypothesis was that the dislocation rate in the PAICO group would be higher than that of the conventional posterior approach with superior capsulotomy (noninferiority analysis). Our alternative hypothesis was that the dislocation rate in the PAICO group would not be higher than that of the conventional posterior approach. Sample size calculations were performed assuming a 2-arm study (PAICO vs. historical control group). This was designed to test the noninferiority of the PAICO versus historical control, with respect to the primary endpoint of dislocation rate within 12 months.

The dislocation rate of the historical control group was derived from a literature review using the conventional posterior approach. In the literature review, the dislocation rate after bipolar hemiarthroplasty ranged from 0.5% to 5%.²¹⁻²⁸⁾ Based on the literature review, the dislocation rate in the historical control group could be assumed to be 1%, and our sample size calculation was based on this. Assuming a 12-month dislocation rate of 1% for the conventional hemiarthroplasty, no difference between groups, a noninferiority margin of 5%, a 1-sided type 1 error of 0.05, a sample ratio (sample size/control size) of 200, and a total

sample size of 25 patients in the PAICO group would provide 80% power to show the noninferiority of the PAICO using the chi-square test.

Statistical Analysis

Continuous data are expressed as mean \pm standard deviation. Categorical data are reported as numbers and percentages. After testing for normal distribution with the Kolmogorov-Smirnov and the Shapiro-Wilk test, the independent sample *t*-test or Mann-Whitney *U*-test was used for continuous variables, and the chi-square tests or Fisher's exact test for categorized data. To determine confounding factors, univariate comparisons between the PAICO group and the historical control group were made based on the demographic data, including age, sex, and BMI.

Multivariable logistic regression analyses were performed with all variables with a *p*-value less than 0.1 in the univariate analyses. The independent variables tested for the multivariable logistic regression analyses included age and BMI as confounding factors; the dependent variable was whether the dislocation occurred within 1 year after the surgery. From the multivariable regression analyses, it was assessed which variables were the independent risk factors for the occurrence of dislocation.

Statistical inferences were made on the basis of a two-sided significance level of *p* < 0.05. All analyses were performed using IBM SPSS version 22.0 for Windows (IBM Corp.).

RESULTS

The PAICO was used to operate on 25 patients (PAICO group: 8 men and 17 women). The mean age of the patients at the operation was 80.8 years (range, 57.2–93.6 years) and the mean BMI was 22.3 kg/m² (range, 15.3–31.1 kg/m²). The posterior approach with superior capsulotomy was used to operate on 3,477 patients (historical control group), of whom 956 were men and 2,521 were women. The mean age of the patients at the operation was 79.4 years (range, 50–102 years) and the mean BMI was 21.7 kg/m² (range, 12.4–33.2 kg/m²). The mean follow-up period was 29.2 months (range, 0–135.5 months).

Operative Parameters

The mean operation time was 70.4 minutes (range, 45–105 minutes) in the PAICO group and 67.2 minutes (range, 30–145 minutes) in the historical control group (*p* = 0.46). The length of hospital stay was 11.4 days (range, 5–58 days) in the PAICO group and 18.4 days (range, 3–146 days) in the historical control group (*p* = 0.03) (Table 2).

Table 2. Operative Parameters

Variable	PAICO group (n=25)	Control group (n=3,571)	p-value
ASA			0.83
1	1 (4.0)	283 (7.9)	
2	11 (44.0)	1,721 (48.2)	
3	13 (52.0)	1,508 (42.2)	
4	0	59 (1.5)	
Cup size (mm)	46.1 ± 3.7	46.1 ± 3.16	0.98
Operation time (min)	70.4 ± 15.3	67.2 ± 21.5	0.46
Length of hospital stay (day)	11.4 ± 10.8	18.4 ± 15.9	0.03

Values are presented as number (%) or mean ± standard deviation. PAICO: posterior approach and inferior capsulotomy, ASA: American Society of Anesthesiologists.

Complications

In the PAICO group, there were no hip dislocations, stem loosening, osteolysis, periprosthetic fractures, periprosthetic joint infections, leg length discrepancy (LLD), nerve injury, vessel injury, heterotrophic ossification, deep vein thrombosis, pulmonary embolism, or myocardial infarction. On the other hand, 7 stem loosening (0.2%), 52 osteolysis (1.5%), 73 periprosthetic fractures (2.0%), 49 periprosthetic joint infections (1.4%), 19 LLD (0.5%), 11 nerve injuries (0.3%), 154 heterotrophic ossification (4.3%), and 28 venous thromboembolisms (0.8%) occurred in the historical control group. While there were no hip dislocations in the PAICO group, 47 hip dislocations (1.3%) occurred in the historical group in the first year after surgery (Table 3).

DISCUSSION

In this prospective study with the historical control group, we demonstrated that the PAICO approach was noninferior to the conventional posterior approach and superior capsulotomy in bipolar hemiarthroplasty for displaced femoral neck fractures. Moreover, the PAICO technique showed no dislocation after surgery.

Considering the zona orbicularis of the hip joint capsule as the key structure for hip stability, repair of capsulotomy to restore locking ring wrapping around the femoral neck is very important to reduce the risk of dislocation.²⁹⁾ In addition to the repair, the location of capsulotomy is also important because the direction of dislocation is usually towards the posterosuperior direction of the hip.

Table 3. Perioperative Complications of the PAICO Group and the Historical Control Group

Variable	PAICO (n = 25)	Historical (n = 3,571)	p-value
1-Year dislocation	0	47 (1.3)	0.54
Stem loosening	0	7 (0.2)	0.81
Osteolysis	0	52 (1.5)	0.51
Periprosthetic fracture	0	73 (2.0)	0.57
Periprosthetic joint infection	0	49 (1.4)	0.53
Leg length discrepancy	0	19 (0.5)	0.81
Nerve injury	0	11 (0.3)	0.84
Heterotrophic ossification	0	154 (4.3)	0.25
Venous thromboembolism	0	28 (0.8)	0.63

Values are presented as number (%). PAICO: posterior approach and inferior capsulotomy.

When the hip is flexed, adducted, and internally rotated, the head will move in a posterosuperior manner. Dislocation after THA might be avoided, if the superior capsule was preserved with inferior capsulotomy.

The posterior approach to the hip joint with superior capsulotomy is a representative surgical approach that allows a wide vision of the surgical field. However, previous studies reported up to 10% high rate of dislocation after the posterior approach because of the injury to the posterior capsule.¹²⁻¹⁵⁾ The PAICO group in this study had a dislocation rate of 0%, although the statistical comparison of the findings between the 2 groups did not reveal superior outcomes in the dislocation. The superior capsule has been preserved as a result of the inferior capsulotomy. Some studies have emphasized the importance of preserving posterior soft tissue by repairing the posterior capsule and soft tissue to decrease dislocation.^{11,12,16-18,30)} White et al.¹²⁾ proposed posterior approaches include posterior capsular and short external rotator repair when comparing groups of complete posterior capsulectomy and of posterior capsule and short external rotator repair; 52 of 1,078 primary total hip replacements (4.8%) had an early posterior dislocation within the first 6 months after operation in patients with a complete posterior capsulectomy, whereas in patients with posterior capsular and short external rotator repair, 3 of 437 primary total hip replacements (0.7%) had an early posterior dislocation. Moon et al.³¹⁾ reported short external rotator repair using the tendon-to-bone technique with drilling to the trochanter (1.1%) reduced

the postoperative dislocation rate compared to that of the tendon-to-tendon repair group (7.5%) ($p=0.041$). Weeden et al.³²⁾ reported only 9 dislocations (0.85%) occurred in 945 total hip arthroplasty procedures and short external rotator repair using tendon-to-bone repair without drilling prevented dislocation.

Some studies introduced modified capsulotomies to preserve posterior soft tissue in order to prevent dislocations in the posterior approach. Capuano et al.³³⁾ used a tissue-preserving technique by piriformis release and superior capsulotomy without the release of short external rotators in total hip arthroplasty and reported favorable results compared to the conventional posterior approach. In 2019, Yilmaz³⁴⁾ more specifically compared effects of the method of capsulotomy (longitudinal versus conventional T-shape) with the identical posterior approach. He reported that no dislocation was observed in 146 patients who underwent bipolar hemiarthroplasty through the posterior approach with longitudinal capsulotomy and significant difference ($p = 0.007$) was found in the rate of postoperative dislocation compared to the posterior approach (5%) with T-shape capsulotomy.³⁴⁾ Martinez et al.¹⁸⁾ reported that only 1 dislocation of 88 patients (1.1%) occurred after hemiarthroplasty with the modified posterior approach preserving the piriformis and the labrum increased the stability of hemiarthroplasty, in comparison to the 7 dislocations of 95 patients (7.4%) in the classical posterior approach ($p < 0.05$).

There are some disadvantages of the PAICO approach. As capsulotomy is located inferiorly, the direct visualization of the hip joint can be limited, and it is not easy to remove the ligament teres. This disadvantage can make it difficult to apply the PAICO to total hip arthroplasty. In our study, proper femur placement with flexion, internal rotation, and adduction allowed sufficient vision for surgery and achieved satisfactory clinical results. In addition, the limited capsular window requires caution during the reduction of the hip after implantation. Excessive rotational force during difficult reduction can result in torsional force in femoral shaft during reduction and create an intraoperative femoral fracture. There was no iatrogenic fracture in our series.

There are some limitations of our study. First, it did not involve random allocation and it was susceptible to bias in interpreting the results. Second, the various implants were used in the control group, while the single implant was used in the PAICO group. Third, the sample size was too small; however, our prior sample size calculation demonstrated that a total sample size of 25 patients in the PAICO group would provide 80% power to show the non-

inferiority of the PAICO using the chi-square test. Last, most study variables and results did not reveal any statistically significant differences between the 2 groups. However, the length of hospital stay was longer in the control group. Although a longer hospital stay may be considered a health difference between the 2 groups, hospitals' strategies to shorten hospital stay are becoming more and more apparent as a possible explanation.

As we know, the standard posterior approach is commonly used for hemiarthroplasty by many orthopedic surgeons worldwide. Surgeons familiar with a posterior approach can apply our PAICO approach easily and directly without any learning curve.

PAICO is an effective surgical technique for bipolar hemiarthroplasty in patients with displaced femoral neck fracture. In the present study, PAICO showed no dislocation after surgery and did not increase operation time and any perioperative complications. We recommend this PAICO approach to surgeons using the posterior approach hoping to prevent dislocation in bipolar hemiarthroplasty.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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SUPPLEMENTARY MATERIAL

Supplementary material is available in the electronic version of this paper at the CiOS website, www.ecios.org

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