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ORIGINAL ARTICLE

The risk factors of early acetabular failure after bipolar hemiarthroplasty because of fracture of the femoral neck

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Abstract

Background: The aim of this study was to evaluate the influence of leg length discrepancy in geriatric patients with early failure of bipolar hemiarthroplasty and to identify related failure patterns and risk factors.

Methods: In this retrospective study, the risk factors of early acetabulum failure within 5 years of hemiarthroplasty for displaced femoral neck fracture were compared with a control group of patients who had implant survival for at least 5 years after hemiarthroplasty. The basic data, leg length discrepancy, femoral offset, and the shell size were evaluated.

Results: Of all risk factors, there was a significant difference in increased leg length between the two groups. The mean difference in leg length was 7.8 ± 5.9 mm in the early acetabular failure group and −1.7 ± 6.2 mm in the control group. For an increase in leg length of >6 mm, the odds ratio of early acetabular failure was 25-fold greater when compared with the control group.

Conclusion: Increased leg length was significantly associated with early acetabular failure after bipolar hemiarthroplasty for femoral neck fracture among geriatric patients. It is critical to avoid increase in leg length after bipolar hemiarthroplasty.

Keywords: Femoral neck fracture; Hip hemiarthroplasty; Implant failure; Leg length discrepancy

1. INTRODUCTION

Bipolar hemiarthroplasty is a common procedure for displaced femoral neck fracture with a long-term implant survival of >10 years in 93.6% to 97% of patients.[1–5] Although the use of total hip arthroplasty and hemiarthroplasty for geriatric patients remains controversial, evidence has revealed lower complication and dislocation rates with hemiarthroplasty.[3,6]

Leg length discrepancy has been studied extensively in total hip arthroplasty.[7] However, its occurrence after hemiarthroplasty has not been discussed adequately. An increase in leg length after hemiarthroplasty theoretically increases pressure on the acetabulum and may lead to failure of the acetabular cartilage.[8] Because 50% to 60% of geriatric patients died within 5 years after hip hemiarthroplasty for femoral neck fracture, early failure of hip arthroplasty was defined as implant survival in <5 years.[9,10] Early acetabulum failure can be catastrophic. Radiological change of acetabular failure in bipolar hemiarthroplasty may present as advanced osteoarthritic change, acetabular erosion, or acetabular protrusion.[3] Treatment of these conditions may require revising hemiarthroplasty to total hip arthroplasty. However, such invasive surgery may expose elderly frail patients to prolonged surgical time, excessive bleeding, and extensive surgical exposure.[11] Owing to these high surgical risks, early acetabulum failure after hemiarthroplasty should be avoided.

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The authors hypothesize that inappropriate leg length increment after bipolar hemiarthroplasty increases pressure on the acetabulum, which can result in early acetabulum failure. To investigate this hypothesis, leg length discrepancies of a group with early acetabular failure were compared with a matched control group of patients with implants surviving for at least 5 years after hemiarthroplasty.

2. METHODS

2.1. Materials

This retrospective case-control study was performed in a single level III trauma center, and this study was approved by the institution review board.

The study cohort included a total of 48 patients. From January 2010 to December 2015, 16 geriatric patients with early failure of the acetabular component after bipolar hemiarthroplasty for femoral neck fracture were enrolled in this study as an early failure group. The inclusion criteria for the early failure group were age of ≥65 years and an etiology of hemiarthroplasty of acute displaced femoral neck fracture resulting from trauma. Early acetabular failure was defined as failure of the acetabulum within 5 years after bipolar hemiarthroplasty, which needed revision to total hip arthroplasty. Besides, the patients should have ambulatory ability before the fracture. Patients with pathological fracture, impaired hip function before operation, periprosthetic infection, hip prosthesis dislocation, implant subsidence, previous hip surgery, and with an advanced hip arthritis before hemiarthroplasty were excluded. Finally, eight males and eight females (mean age, 73.37 years) were included in the early failure group.

Patients in the control group were selected consecutively from January to December 2010. In this group, all patients had the same etiology for receiving bipolar hemiarthroplasty as those in the early acetabular failure group, and the hip joint survived for at least 5 years after surgery. Besides, the patients in control group should be able to ambulate before fracture. The exclusion criteria for control group were as follows: the implant with subsidence, patients with periprosthetic fracture, and patients with ambulatory impairment during follow-up. A total of 32 patients (22 females and 10 males; mean age, 71.25 years) were enrolled consecutively as a long-term survival group. All the patients had at least 5-year follow-up records. Regarding surgical methods, both groups received stem fixation with noncemented technique and no patient received cemented fixation in the current study.

2.2. Measurements

In all cases, Tönnis classification of osteoarthritis of the hip was used to determine the grade of the injured hip and measured on preoperation pelvic anterior-posterior (AP) radiograph. The initial postoperation leg length discrepancy and femoral offset were recorded during the postoperative 1-month follow-up with standing pelvic AP view. The initial clinical function was reported based on the Harris hip score recorded on postoperative 3-months follow-up.

The final radiological outcome was reported based on standing pelvic AP view on last follow-up and the clinical outcomes were reported based on final clinical follow-up chart recording.

All radiological parameters were measured by a senior resident and the corresponding author with picture archiving and communication system digital measuring instrument by smartIRIS version 13.0 (Taiwan Electronic Data Processing Corporation, New Taipei City, Taiwan). For continuous variables, results were obtained from the mean of two measured values. Different opinions on categorical variables were resolved by discussion. The patient's basic data, age, American Society of Anesthesiologists (ASA) physical classification, Harris hip score, shell size of the bipolar hip prosthesis, and body mass index (BMI) were also documented.

The perpendicular distance of an interteardrop line to the tip of the lesser trochanter was used as a reference point to measure leg length (Fig. 1). The interteardrop line connects teardrops in pelvic AP radiographs. The perpendicular distance from the interteardrop line to the tip of the lesser trochanteric has been described as an effective and precise method to measure leg length discrepancy.[12–14] In this study, leg length discrepancy was calculated by operated leg length minus the contralateral leg length (Fig. 1). A positive value of leg length discrepancy indicates an increase in leg length after surgery, while a negative value indicates that the operated side is shorter. Femoral offset is the perpendicular distance from the center of the femoral head to a line drawn down the center of the femoral shaft (Fig. 2).[13–15] In the current study, side differences in femoral offset were used for calculations.

In the early failure group, the final pattern of the acetabulum was classified into three groups: advanced osteoarthritis change to the hip, acetabular erosion, and acetabular protrusion.[3] Advanced osteoarthritis change to the hip was defined as no clear space between the acetabular subchondral bone and bipolar shell. Acetabular erosion was defined as erosion of the acetabular subchondral cortical bone (Fig. 3), which was not apparent on pelvic AP images, and acetabular protrusion was defined as invasion of the bipolar shell over Kohler's line[16] (Fig. 3). In the long-term survival group, the final radiological and clinical outcomes were reported. Finally, the interobserver reliabilities of preoperative Tönnis classification of hip arthritis, leg length discrepancy, and femoral offset were assessed.

2.3. Statistical analysis

Statistical analysis was performed using SPSS version 19.0 software (IBM-SPSS, Inc., Chicago, IL, USA). The Student's t test and χ^2 test were performed for continuous and ordinal variates, respectively. The Pearson correlation coefficient was used for evaluating the correlation of two continuous variates. For all tests, a probability (p) value of <0.05 was considered statistically significant. For multiple variates analysis, variates with statistical significance under univariate analysis were processed into multiple logistic analyses. The optimal threshold for leg length increment was calculated according to the area under the receiver operating characteristic (ROC) curve. Interobserver reliability was evaluated with intraclass correlation coefficients for continuous variables and kappa coefficients for ordinal variables, and 95% confidence intervals were calculated for both. Regarding power analysis, we use G*Power to calculate.[17]

3. RESULTS

A total of 48 patients were enrolled in this study. To evaluate interobserver reliability of the pre and postoperative variables, intraclass correlation coefficients and kappa coefficients were calculated (Table 1). The measurement reliability of the Tönnis classification for grading hip arthritis indicated moderate to good reliability.[18] Besides, measurement of leg length discrepancy had a single-measure intraclass coefficient 0.80 and average-measure intraclass coefficient of 0.88, indicating good reliability.[18]

There were no significant differences in age, sex distribution, ASA classification, BMI, injury side, and initial Harris hip score between the early failure group and control group (Table 2). Also, there were no significant differences of preoperative Tönnis grade between the early acetabular failure group and long-term survival group (Table 2).

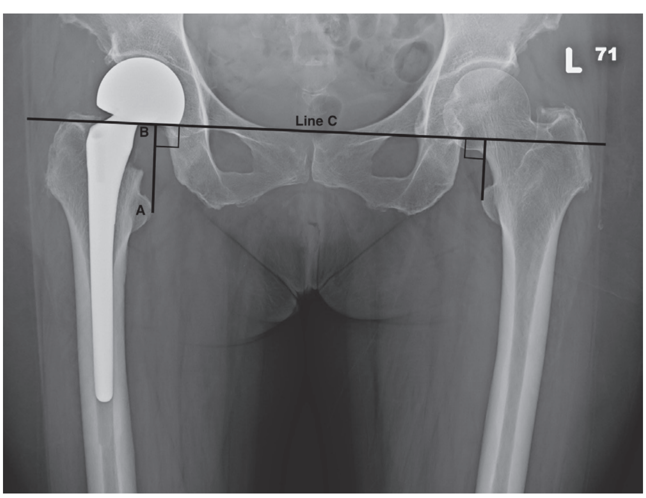

Fig. 1 Measurements of leg length discrepancy: The leg length (point A to B) is measured by the distance from tip of lesser trochanter (point A) perpendicular to the inter-teardrop line (line C).

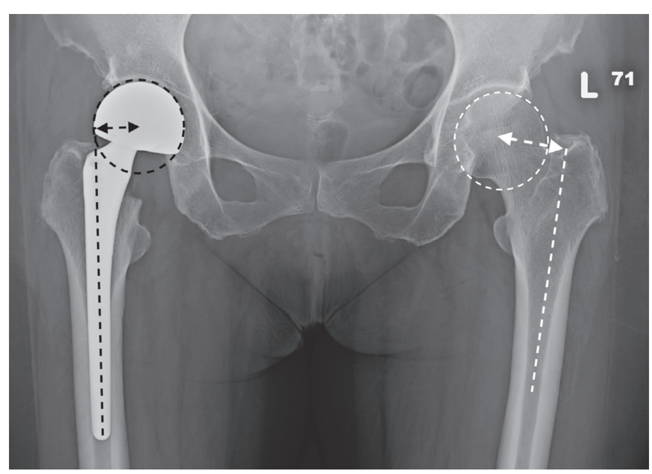

Fig. 2 Measurement of offset: The femoral offset (distance A to B) is measured by the distance perpendicularly from the femoral anatomical axis (Line F) to the center of rotation of the femoral head (Point B).

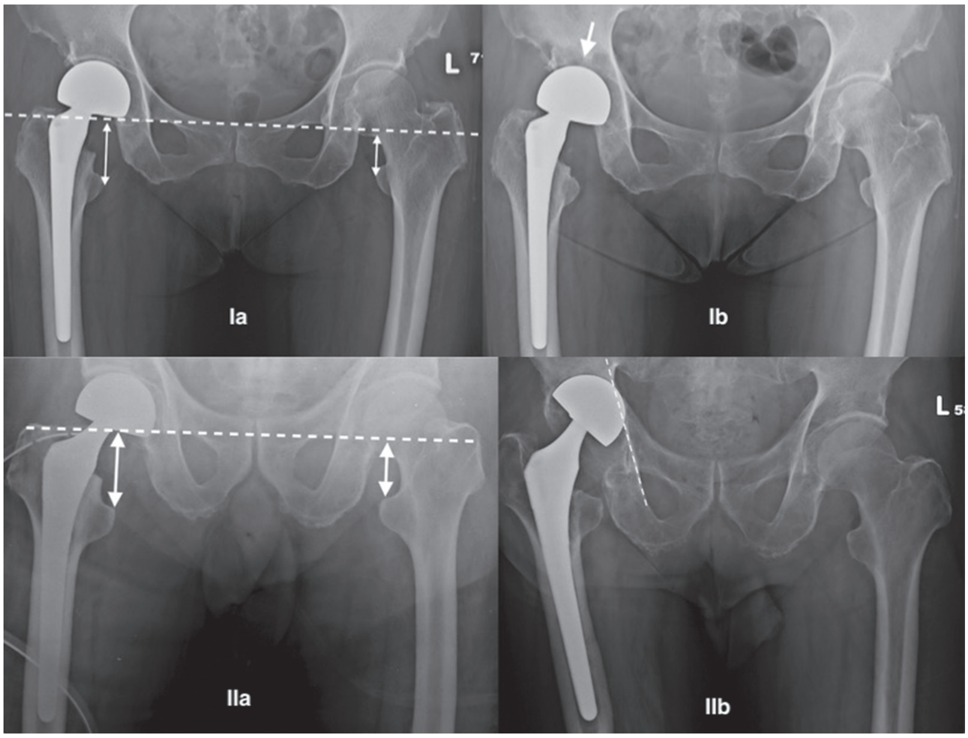

Fig. 3 Examples of increased leg length after hemiarthroplasty and subsequent early acetabulum failure. Case I: acetabulum erosion at 6-months follow-up (Ib). Case II: acetabulum protrusion at 2-year follow-up (IIb); the thin dash line is the Kohler's line (ilioischial line).

Table 1

Reliability between the two observers

Variable	Intraclass correlation coefficient or kappa coefficient	95% CI
Preoperative of the hip		
Tönnis classification		
Kappa coefficient	0.60[a]	0.47-0.73
Leg length discrepancy		
Single measure	0.80[b]	0.67-0.88
Average measure	0.88	0.80-0.93
Femoral offset		
Single measure	0.69[b]	0.51-0.81
Average measure	0.81	0.67-0.89

[a]Kappa coefficient.
[b]Intraclass correlation coefficient.

Table 2

Overview of the two groups

Factors	Early failure group (n = 16)	Long-term survival group (n = 32)	p
Sex			0.22
Female	8	22	
Male	8	10	
Age (y)	73.37± 8.83	71.25±9.57	0.46
ASA classification			0.61
I	1	1	
II	11	26	
III	4	5	
Injury side			0.75
Right	6	17	
Left	10	15	
BMI	24.01 ± 5.05	24.13 ± 3.27	0.92
Tönnis classification of preoperative hip arthritis[a]			0.63
0	2	2	
1	13	26	
2	1	4	
3	0	0	
Initial Harris Hip Score just after operation	81.35 ± 3.77	83.43 ± 4.31	0.11

ASA classification = American Society of Anesthesiologists physical status classification; BMI = body mass index.
[a]Grade I, no osteoarthritis change; Grade IV, advanced osteoarthritis change.

Initial postoperative radiographs revealed a significant difference in leg length discrepancies between the early failure group and control group (Table 3). The mean increased leg length discrepancy was 7.8 ± 5.9 mm (0-17.6 mm) in the early acetabular failure group and −1.7 ± 6.2 mm in the control group ($p = 0.001$). The statistic power of this finding is 99%. Regarding offset and shell size, there was no significant difference between the two groups (Table 3).

In early-failure group, there were advanced wear of the acetabular cartilage observed in two patients, acetabular erosion was observed in seven patients, and acetabular protrusion was observed in seven patients (Table 4). All the patients in early group received revision to total hip arthroplasty to restore the function. The final Harris hip score in early failure group is 34.85 ± 13.72 (Table 4). The acetabular erosion and protrusion accounted for the majority of early acetabular failure cases (14/16). The mean implant survival time of early acetabular failure group was 2.29 ± 1.25 years (0.66-4.9 years) (Table 4). There were two patients with implant survival of <1 year, 12 patients with implant survival of <3 years, and two patients with implant survival of <5 years. There was no significant linear correlation of implant survival time with leg length discrepancy (Pearson correlation = 0.189, $p = 0.48$). In the long-term survival group, the mean follow-up period was 5.3 ± 0.58 years. At final follow-up, the mean Harris hip score in long-term survival group is 81.11 ± 4.70.

The area under the ROC curve was 0.88 (Fig. 4). With Youden index to evaluate the optimal cut-point, the optimal cut-off value for leg length increment after hemiarthroplasty was around 6 mm. There was a significant difference in outcome between patients with a leg length increment of ≤6 mm and >6 mm ($p = 0.001$). Patients with leg length increment >6 mm had a

Table 3

Risk factors in the early failure group and long-term survival group

	Early failure group (n = 16)	Long-term survival group (n = 32)	*p*
Leg length discrepancy (mm)[a]	7.8 ± 5.9	−1.7 ± 6.2	<0.001*
Femoral offset (mm)[b]	0.1 ± 8.3	0.8 ± 4.9	0.72
Shell size (mm)	47.0 ± 2.1	46.6 ± 2.4	0.56

*Statistical significance was defined as $p < 0.05$.

[a]Operation side leg length minus contralateral side leg length; a positive value indicates that the operated side is longer and a negative value indicates that the operated side is shorter.

[b]Operation side femoral offset minus contralateral femoral offset.

Table 4

Outcomes in the early failure group and long-term survival group

	Early failure group (n = 16)	Long-term survival group (n = 32)	*p*
Final outcomes			
Survival	0	32	<0.001*
Advanced osteoarthritis	2	0	
Acetabulum erosion	7	0	
Acetabulum protrusion	7	0	
Time to failure (y)	2.29 ± 1.25	Nil	Nil
Final Harris Hip Score	34.85 ± 13.72	81.11 ± 4.70	<0.001*

*Statistical significance was defined as $p < 0.05$.

25-fold greater risk for early acetabular failure, when compared with those of leg length increment ≤6 mm. In the early acetabular failure group, there were 10 patients with leg length increment of >6 mm, and seven of them had increased leg length of >10 mm.

4. DISCUSSION

Arthroplasty is an effective treatment method for displaced femoral neck fractures in geriatric patients, resulting in fewer major surgical complications, lower reoperation rates, better pain relief, and quicker functional recovery than with internal fixation.[2,19] Although some studies suggested that functional recovery is better with total hip arthroplasty than hemiarthroplasty, dislocation is more common after total hip arthroplasty.[6] A national study revealed a lower revision rate and greater long-term implant survival rate with bipolar hemiarthroplasty when compared with total hip arthroplasty.[3] These findings indicate that bipolar hemiarthroplasty is an optimal treatment for displaced femoral neck fractures in geriatric patients.

Complications of leg length discrepancy after total hip arthroplasty, such as increased incidences of back pain, sciatica, gait disorders, and dislocation rates, have been well documented.[7] However, few studies have investigated leg length discrepancies after bipolar hemiarthroplasty. The results of the current study demonstrated that increased leg length after bipolar hemiarthroplasty was strongly associated with early acetabulum failure. Besides, acetabular erosion and acetabular protrusion accounts for most of the early failure cases.

Acetabulum erosion accounted for 4.8% to 5.1% of all revision cases after bipolar hemiarthroplasty.[3] Various causes of acetabulum erosion have been proposed including direct injury during the original incident, excessive pressure on the acetabulum, mismatch between the acetabulum and the diameter of the prosthetic head, as well as wearing of the hard metallic head against the acetabular cartilage.[20] In the current study, we confirmed that increased leg length would induce early acetabular failure. In 2004, Perttunen et al.[21] analyzed 25 patients with

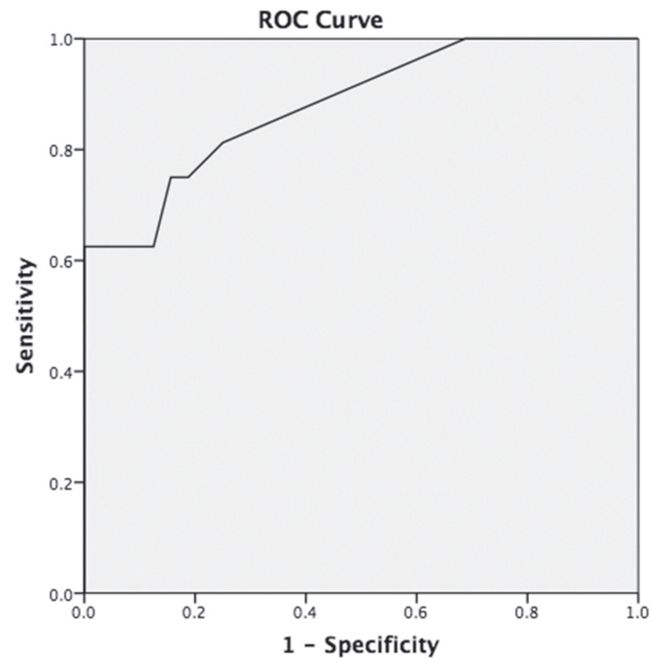

Fig. 4 The receiver operating characteristic (ROC) curve of the increased leg length discrepancy predicts outcome. The area under the curve is 0.881.

leg length discrepancies and found greater loading and longer bearing duration of the longer limb. This means the effect of leg length increment does not only merely results in increased pressure on the acetabulum by soft tissue tension but also increases the maximum load and weight-bearing duration of the longer leg while walking.

Despite no statistical significance, the offset in early failure group was less than the survival group. The less offset theoretically decreases the pressure over the acetabulum, and could be regarded as a negative confounding factor, which has protective effect to our result.

There was no significant linear correlation between leg length discrepancy and implant survival duration. However, the mean increased leg length discrepancy was 5.9 ± 6.2 mm and 11.5 ± 3.8 mm for patients with acetabular erosion and acetabular protrusion, respectively. The *p* value of difference in leg length discrepancy for these two subgroups was 0.065. Although not statistically significant, there is a trend that patients with acetabulum protrusion tended to have a longer leg length, when compared with patients with acetabulum erosion.

Because of the devastating consequences of early acetabulum failure after bipolar hemiarthroplasty, avoiding leg length increment is crucial. Multiple reports have described the importance of preventing leg length discrepancy during total hip arthroplasty.[7,22] Although the number of studies focussing on how to decrease leg length discrepancy after bipolar hemiarthroplasty is limited, the general rules to prevent leg length discrepancy after total hip arthroplasty can also be applied to bipolar hemiarthroplasty. Most of these methods can be grouped into perioperative templating or use of intraoperative femoral and pelvic land markers as references to prevent leg length discrepancies.[23] These methods, although not perfect, should be considered to prevent leg length discrepancies. Based on our experience, perioperative templating, soft tissue tension after reduction, repair of the joint capsule, and comparisons with the contralateral leg during surgery, all can assist to estimate leg length after bipolar hemiarthroplasty.

Despite the fact that this study has presented some preliminary results, there were limitations. First, because this study was both retrospective and observational as well, intrinsic bias existed in data collection. However, the reliability of the measurements was assessed and found that the interobserver reliability is moderate to good. Besides, patients were consecutively enrolled in both groups to decrease the impact of selection bias. Second, due to the low incidence of early failure of acetabular failure after bipolar hemiarthroplasty and long follow-up duration of the study, only 16 patients were in the early failure group, which led to a large confidence interval. Therefore, further extensive studies are needed to verify these conclusions.

In conclusion, the results of the current study demonstrated that an increase in leg length was significantly associated with early acetabulum failure after hemiarthroplasty for femoral neck fracture in geriatric patients. To avoid early acetabulum failure after hemiarthroplasty, equal or only slight differences in leg length after hemiarthroplasty is advised.

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