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Factors affecting dislocation after bipolar hemiarthroplasty in patients with femoral neck fracture

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ABSTRACT

Purpose: This study aimed to investigate the anatomic risk factors associated with dislocation following bipolar hemiarthroplasty for the treatment of femoral neck fracture.
Materials and Methods: We retrospectively reviewed 208 consecutive patients (133 women, 75 men) with femoral neck fractures who were treated with bipolar hemiarthroplasty between 2015 and 2018. A comparative analysis was performed between dislocation ($n = 18$) and non-dislocation ($n = 190$) groups in terms of patient demographics, surgical and pelvic morphologic factors, and clinical outcomes, including postoperative Harris and modified Harris hip scores. Independent risk factors affecting dislocation were also evaluated.
Results: The mean follow-up period was 30.8 ± 2.0 (range, 12–48) months. The mean age was 79.2 ± 7.4 (range, 71–94) years. The dislocation rate was 8.6% (18/208), and the mean dislocation time after operation was 2.0 ± 1.1 (range, 1–4) months. Patient-related factors did not differ between the dislocated and non-dislocated groups. As regards dislocation, statistically significant difference was observed in surgical and pelvic morphologic factors, including femoral offset, residual femoral neck length, trochanter upper end and femoral head center distance, and height of the hip center of the operated side ($p = 0.025$, $p = 0.013$, $p = 0.002$, $p = 0.008$, respectively). Moreover, the femoral offset, height of the hip center, and femoral neck-shaft angle of the non-operated side are significantly different between the groups ($p = 0.007$, $p = 0.001$, $p = 0.027$, respectively). Decrease in the center edge (CE) angle, offset of prosthesis, and increase in femoral head extrusion index (FHEI) of the operated side and decrease in the height of the hip center of the non-operated side increased the risk of dislocation ($p = 0.030$, OR: 1,306; $p = 0.041$, OR: 8.15; $p = 0.020$, OR: 1.038; $p = 0.010$, OR: 2.02, respectively).
Conclusions: Pelvic morphologic features and surgical factors were found to affect dislocation. Patients with smaller OP, CE angle of the operated side, and higher FHEI and smaller height of the hip center of the non-operated side should be carefully monitored to decrease postoperative dislocation.

Introduction

The incidence rate of hip fractures is increasing with increasing average life span and social activities in elderly patients. In this patient population, the main goal after a hip fracture is to try to return to performing daily activities at pre-fracture levels as soon as possible to prevent complications [1].

Surgical options for displaced adult femoral neck fractures include closed/open reduction internal fixation, total hip arthroplasty, and hemiarthroplasty. Arthroplasty is a widely accepted treatment because it allows early patient mobilization. Open reduction and internal fixation is rarely used for femoral neck fractures in an elderly population because of high nonunion rates and poor functional outcomes after transition to arthroplasty [2]. Hemiarthroplasty offers a better alternative to displaced femoral neck fractures than open reduction and internal fixation when con-

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sidering factors such as complications, revision rate, and health-related quality of life [2]. Moreover, hemiarthroplasty is the preferred treatment because it is a shorter and relatively simple procedure with less blood loss compared to total hip arthroplasty. In addition, its reported dislocation rate is lower than that of total hip arthroplasty [3–5]. Although its incidence is lower than that of total hip arthroplasty, dislocation in hemiarthroplasty remains consistently occur and can increase the mortality and morbidity rates in elderly patients [6].

Hemiarthroplasty dislocation is a serious complication with incidence rates ranging from 1.5% to 16% [7–9]. Various risk factors for dislocation related to the patient or surgery have been reported [8,10–12]. Some of the causes of patient-related risk factors are neurological disorders; abductor muscle weakness; hip joint deformities, where surgery-related dislocations were associated with different surgical approaches, prosthetic; and other problems [10]. In several recent studies, femoral offset, leg-length discrepancy, and acetabular center edge (CE) angle have been identified as potential factors affecting the dislocation rates [8,11,12]. However, a comprehensive evaluation was not performed.

In this study, we aimed to investigate factors that may cause dislocation following a bipolar hemiarthroplasty by evaluating the pelvic geometry in addition to the patient characteristics and investigate the incidence of dislocation for the treatment of femoral neck fractures in elderly patients.

Materials and methods

Study population

We retrospectively reviewed the medical records and radiographs of 250 patients who underwent bipolar hemiarthroplasty for femoral neck fracture between June 2015 and April 2018. Of these, 208 consecutive patients (133 women, 75 men with a mean age of 79.2 ± 7.4 years; range, 71–94 years) were finally enrolled, after excluding 42 patients. The inclusion criteria were as follows: [1] patients underwent bipolar hemiarthroplasty through a posterolateral approach, [2] surgery due to displaced femoral neck fracture, and [3] patients attended regular follow-up for at least 1-year. Cementless square prosthesis was used in 120 patients, modular prosthesis in 48 patients, and cemented calcar replacement prosthesis in 40 patients. Patients treated using other approaches or implants, patients with pathological fractures, lower than 1-year follow-up, and previous history of surgery on the ipsilateral side were excluded.

Procedure

Operations were performed in the lateral decubitus position with general or regional anesthesia. Short external rotator tendons were separated including the piriformis muscles, and the quadratus femoris muscles were separated when needed. Short external rotator tendons and posterior joint capsule were repaired while completing surgery in all cases. Immediate weight bearing was allowed by using crutches or wheelchair on the first postoperative day. All patients had rehabilitation under the guidance of a physiotherapist. All patients were advised to avoid >90° of flexion and >45° of internal rotation in hip movements and to avoid excessive hip adduction.

Measures

Pre- and postoperative pelvic anteroposterior (AP) view, standard AP, and lateral radiographs of the femur including the hip joint was evaluated, and hip and pelvis measurements were recorded. Then, a comparative analysis was performed between the dislocation and non-dislocation groups in terms of patient factors including age, sex, operation side, American Society of Anesthesiologists (ASA) score, body mass index (BMI), and comorbidities (diabetes, hypercholesterolemia, thyroid disease, delirium, dementia). Patients were divided into four groups according to the ASA score: Grade I (healthy), Grade II (mild systemic disease), Grade III (moderate systemic disease), and Grade IV (severe systemic disease). Standard AP hip and pelvic radiographs were taken with the patient in the standing position and both legs slightly internally rotated. Radiological measurements were performed by a surgeon who did not perform the actual surgery. The center edge (CE) angle of Wiberg, pelvic height (PH), leg length difference after surgery, offset of the prosthesis, femoral offset, femoral head extrusion index (FHEI), residual femoral neck length (RFNL), major trochanter upper end and femoral head center distance (TEFHCD), height of the hip center, body weight lever arm (BWLA), Sharp's angle - acetabular index, Tönnis angle, femoral neck-shaft angle (FNSA), pelvic obliquity, and type of femoral stem were reviewed retrospectively as dislocation-related surgical and pelvic morphologic factors based on medical records.

Definitions

The CE angle was defined as the angle between the center of the bipolar cup or normal side of the femoral head (opposite side CE) and the lateral edge of the acetabulum. PH was recorded as the distance between two lines, i.e., the inter-ischial line as the first line which was drawn through at the lowest end of the pelvis, and the second line was tangent to the upper end of the ilia. Leg length difference was defined as the difference in the distance between a line passing through the lower edge of the teardrop points and the corresponding tip of the lesser trochanter [7]. Offset of the prosthesis was defined as the distance between the center of the femoral head to the longitudinal axis of the femur. Femoral offset was measured as the sum of offset of the prosthesis plus the distance between the center of the femoral head to perpendicular distance passing through the medial margin of the ipsilateral teardrop point. Femoral head lateralization over the acetabular edge was defined as FHEI [13]. RFNL was the distance measured between residual length of the medial cortex of the femoral neck after hemiarthroplasty and the line drawn from the center of the trochanter minor parallel to the ground. TEFHCD was measured as the distance between the center of the femoral head and the top of the trochanter major. Height of the hip center was measured as the distance from the center of the femoral or prosthetic head, perpendicular to the inter-ischial line which was drawn through at the lowest end of the pelvis. BWLA was defined as the distance from the center of the femoral head to the line of the center of gravity. The angle of inclination of the acetabulum (Sharp's angle) – acetabular index angle – was measured as previously described [13]. Tönnis angle (the acetabular index of the weight-bearing zone), which evaluates the orientation of the acetabular roof, was measured as previously identified [13]. FNSA was defined as the angle made by the intersection of the longitudinal axis of the neck with that of the longitudinal axis of the femoral shaft. Pelvic obliquity was determined on AP pelvis radiographs by measuring the iliolumbar angle using the convergence of two lines of the tangent to the upper end of the ilium and the line along the bottom of the fourth lumbar vertebra. All measurements of the affected and healthy sides were evaluated and compared for all patients. Clinical outcomes including postoperative Harris [14] and modified Harris hip scores [15] were evaluated according to the dislocation status. Independent risk factors affecting dislocation were also evaluated.

This study was approved by the Institutional Review Board of our hospital and informed consent was obtained from all the participants.

Table 1
Patient characteristics according to the dislocation status.

		Total		Dislocation (-)		Dislocation (+)		
		Mean ± SD / n-%	Median (min-max)	Mean ± SD/n-%	Median (min-max)	Mean ± SD/n-%	Median (min-max)	p value
Age (years)		79.2 ± 7.4	80.0 (61–94)	79.3 ± 7.6	80.0 (61–94)	78.5 ± 6.1	78.0 (68–88)	0.431
BMI (kg/m^2)		24.2 ± 2.7	24.2 (18.6–33.3)	24.3 ± 2.7	24.5 (18.6–33.3)	23.3 ± 2.3	23.1 (19.6–30.2)	0.139
ASA	I	32 15.4%		29 90.6%		3 9.4%		0.584
	II	55 26.4%		50 90.9%		5 9.1%		
	III	103 49.5%		96 93.%		7 6.8%		
	IV	18 8.7%		15 83.3%		3 16.7%		
Sex	Female	133 63.9%		122 91.7%		11 8.3%		0.794
	Male	75 36.1%		68 90.7%		7 9.3%		
Side	Right	89 42.8%		83 93.3%		6 6.7%		0.396
	Left	119 57.2%		107 89.9%		12 10.1%		
Diabetes	(-)	168 80.8%		154 91.7%		14 8.3%		0.736
	(+)	40 19.2%		36 90.0%		4 10.0%		
Hypercholesterolemia	(-)	146 70.2%		134 91.8%		12 8.2%		0.732
	(+)	62 29.8%		56 90.3%		6 9.7%		
Thyroid	(-)	199 95.7%		181 91.0%		18 9.0%		0.345
disease	(+)	9 4.3%		9 100.0%		0 0.0%		
Delirium	(-)	174 83.7%		158 90.8%		16 9.2%		0.530
	(+)	34 16.3%		32 94.1%		2 5.9%		
Dementia	(-)	165 79.3%		150 90.9%		15 9.1%		0.661
	(+)	43 20.7%		40 93.0%		3 7.0%		
Follow-up (months)		30.8 ± 12.0	36.0 (12–48)	31.2 ± 12.0	36.0 (12–48)	26.0 ± 10.2	24.0 (12–48)	0.073

Statistical analysis

Data were recorded and analyzed using SPSS, version 22.0, for Windows (SPSS Inc., Chicago). The distribution of the variables was assessed using the Kolmogorov-Smirnov test. Mean, standard deviation, median, lowest and highest values, and frequency ratio were used in the descriptive statistics of data. Independent sample *t*-test and Mann–Whitney U test were used in the analysis of quantitative independent data. Chi-square test was used in the analysis of qualitative independent data, and Fisher exact test was used when the chi-square test conditions were not met. Binary logistic regression analysis was used to determine independent risk factors affecting dislocation. For all tests, p values of < 0.05 were considered significant.

Results

Among 208 hemiarthroplasty cases, dislocation occurred in 18 of 208 cases (8.6%) during follow-up, and all dislocations followed a posterior direction. The mean patient age was 79.2 ± 7.4 (range, 71–94) years. The mean follow-up period was 30.8 ± 12.0 (range, 12–48) months. The mean dislocation time after operation was 2.0 ± 1.1 (range, 1–4) months. Patient-related factors did not differ between the dislocated and non-dislocated groups. Patients' characteristics are summarized in Table 1.

As regards dislocation, statistically significant difference was observed in surgical and pelvic morphologic factors including femoral offset, RFNL, TEFHCD, and height of the hip center of the operated side ($p = 0.02$, $p = 0.013$, $p = 0.002$, $p = 0.008$, respectively) (Fig. 1). In addition, femoral offset, height of the hip center, and FNSA of the non-operated sides were significantly different between the groups ($p = 0.007$, $p = 0.001$, $p = 0.027$, respectively). Surgery-related and pelvic morphologic features are summarized in Table 2. The type of prosthesis used and clinical outcomes were not statistically different between the dislocated and non-dislocated groups, and the outcomes are summarized in Tables 3 and 4.

When independent risk factors affecting dislocation were evaluated, decreased CE angle, increased offset of the prosthesis, and increased FHEI of the operated side and decreased height of the hip center of the non-operated side were found to increase the risk of dislocation ($p = 0.030$, OR: 1.306; $p = 0.041$, OR: 8.15; $p = 0.020$, OR: 1.038; $p = 0.010$, OR: 2.02, respectively) (Table 5). In the treatment of dislocated cases, closed reduction was attempted primarily in all cases with a first-time dislocation under general anesthesia. In one patient, open reduction was performed after failed closed reduction attempt. There was no recurrence of dislocation but in one patient. In that patient, dislocation recurred four times, and revision surgery with a dual mobility cup total hip arthroplasty was performed. No further revision surgeries were performed thereafter.

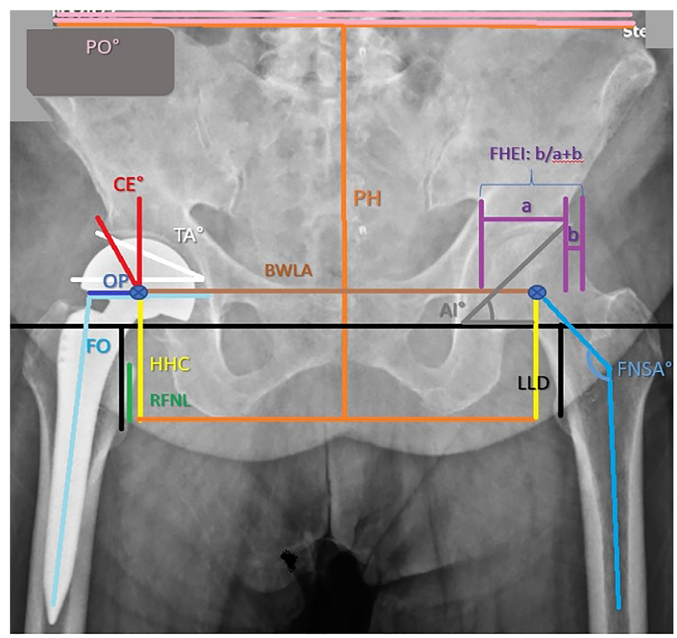

Fig. 1. Comparative pelvic measurement parameters in a dislocated and non-dislocated patient.

Discussion

This study mainly found that pelvic morphologic features and surgical factors affect hemiarthroplasty dislocation. Decreased CE angle, increased offset of the prosthesis, and increased FHEI on the operated side and decreased height of the hip center on the non-

Table 2
Surgery-related and pelvic morphologic features according to the dislocation status.

	Total		Dislocation (-)		Dislocation (+)		
	Mean ± SD / n-%	Median (min-max)	Mean ± SD / n-%	Median (min-max)	Mean ± SD / n-%	Median (min-max)	*p* value
CE angle° (os)	44.9 ± 6.6	45.0 (30.0–60.0)	45.0 ± 6.5	45.0 (30.0–60.0)	42.8 ± 7.5	43.0 (32.0–58.0)	0.477
CE angle° (ns)	43.3 ± 5.9	43.0 (30.0–58.0)	43.5 ± 6.1	43.0 (30.0–58.0)	41.4 ± 3.3	41.5 (36.0–47.0)	0.161
PH (cm)	22.2 ± 1.4	22.1 (18.9–25.0)	22.3 ± 1.4	22.3 (18.9–25.0)	21.8 ± 1.1	21.6 (20.1–24.2)	0.148
LLH (cm)	0.39 ± 0.72	0.4 ((−1.7)–2.1)	0.41 ± 0.69	0.4 ((−1.7)–2.1)	0.13 ± 0.53	0.0((−1)– 2)	0.097
OP (Offset Prosthesis) (cm)	4.9 ± 0.7	4.9 (2.9–7.0)	4.9 ± 0.7	4.9 (2.9–7.0)	5.0 ± 0.6	5.0 (4.0–5.8)	0.523
ON (Offset ns) (cm)	4.9 ± 0.9	5.0 (2.8–8.0)	5.0 ± 0.9	5.1 (2.8–8.0)	4.9 ± 0.9	4.9 (3.3–6.5)	0.696
FO (os) (cm)	4.0 ± 0.6	4.1 (2.1–4.4)	4.1 ± 0.6	4.1(2.1–3.6)	3.6 ± 0.6	3.9(2.2–4.4)	***0.020***
FO (ns) (cm)	4.0 ± 0.7	4.1 (1.9–5.8)	4.1 ± 0.6	4.1 (1.9–5.8)	3.5 ± 0.8	3.6 (2.0–4.9)	***0.007***
FHEI (os)	0.12 ± 0.04	0.12 (0.02–0.23)	0.11 ± 0.03	0.13 (0.03–0.15)	0.12 ± 0.04	0.12 (0.02–0.23)	0.518
FHEI (ns)	0.11 ± 0.04	0.12 (0.02–0.26)	0.12 ± 0.01	0.12 (0.09–0.15)	0.11 ± 0.04	0.11 (0.02–0.26)	0.537
RFNL (os) (cm)	1.0 ± 0.8	0.9 (0.0–3.2)	0.9 ± 0.8	0.8 (0.0–2.8)	1.4 ± 0.6	1.2 (0.5–3.2)	***0.013***
TEFHCD (os) (cm)	4.7 ± 0.8	4.9 (3.2–6.5)	4.8 ± 0.8	4.9 (3.2–6.5)	4.3 ± 0.4	4.5 (3.7–5.0)	***0.002***
TEFHCD (ns) (cm)	5.0 ± 0.5	5.1 (3.9–6.8)	5.0 ± 0.5	5.1 (3.9–6.8)	4.9 ± 0.5	4.8 (4.2–6.8)	0.324
HHC (os) (cm)	7.1 ± 0.8	7.2 (4.9–10.1)	7.2 ± 0.8	7.2 (4.9–10.1)	6.6 ± 0.7	6.3 (5.9–8.1)	***0.008***
HHC (ns) (cm)	7.1 ± 0.7	7.1 (5.2–9.1)	7.1 ± 0.6	7.1 (5.2–9.1)	6.5 ± 0.7	6.5 (5.5–7.9)	***0.001***
BWLA (os) (cm)	9.4 ± 0.7	9.4 (7.7–11.4)	9.4 ± 0.6	9.4 (7.7–11.4)	9.3 ± 0.9	9.1 (8.2–11.0)	0.560
BWLA (ns) (cm)	9.6 ± 0.7	9.7 (7.5–11.2)	9.6 ± 0.7	9.7 (7.5–11.2)	9.5 ± 0.8	9.7 (7.8–10.8)	0.514
AI° (os)	35.6 ± 4.7	36.0 (22.0–47.0)	35.7 ± 4.7	36.0 (22.0–47.0)	34.3 ± 4.8	33.0 (28.0–44.0)	0.145
AI° (ns)	34.1 ± 4.5	34.5 (23.0–45.0)	34.2 ± 4.5	34.5 (23.0–45.0)	33.6 ± 4.7	34.5 (27.0–38.0)	0.589
TA (os)	9.4 ± 5.2	9.0 (3.0–29.0)	9.6 ± 5.3	10.0 (3.0–29.0)	7.6 ± 4.2	8.0 (3.0–14.0)	0.133
TA° (ns)	10.3 ± 5.1	10.0 (3.0–22.0)	10.2 ± 5.2	10.0 (3.0–22.0)	11.0 ± 3.9	13.0 (5.0–16.0)	0.517
FNSA° (os)	143.3 ± 6.6	145.0 (130.0–160.0)	143.3 ± 6.57	145.0 (130.0–160.0)	142.7 ± 6.6	142.0 (135.0–150.0)	0.697
FNSA° (ns)	139.5 ± 7.4	140.0 (122.0–156.0)	139.2 ± 7.4	140.0 (122.0–156.0)	142.8 ± 6.8	145.0 (132.0–151.0)	***0.027***
PO°	0.39 ± 3.2	0.0 (−9.0–7.0)	0.48 ± 3.2	0.0 (−9.0–7.0)	−0,5 ± 5.4	−1.0 (−6.0–5.0)	0.169

CE: Center Edge, PH: Pelvic High, LLH: Leg Length Difference, FHEI: Femoral Head Extrusion Index, RFNL: Residual Femoral Neck Length, TEFHCD: Major Trochanter Upper End and Prosthetic Head Center Distance, FO: Femoral Offset, HHC: Height of Hip Center, BWLA: Body Weight Lever Arm, AI: Acetabular Index, TA: Tönnis Angle, FNSA: Femoral Neck-Shaft Angle, PO: Pelvik Obliquity. (os): Operated Side, (ns): Non-operated Side.

Table 3
Comparison of dislocation status according to prothesis type.

		Total n-%	Dislocation (-) n-%	Dislocation (+) n-%	*p* value
Prothesis type	Cementless squared	120–57.7	106–88.3	14–11.7	0.191
	Modular	48–19.2	46–95.8	2–4.2	
	Cemented calcar replacement	40–23.1	38–95	2–5	

Table 4
Comparison of clinical outcomes according to dislocation status.

	Total		Dislocation (-)		Dislocation (+)		
	Mean ± SD /n-%	Median (min-max)	Mean ± SD / n-%	Median (min-max)	Mean ± SD / n-%	Median (min-max)	*p* value
Harris Score	65.1 ± 19.5	64.6 (21.0–100.0)	65.4 ± 19.4	65.0 (21.0–100.0)	62.2 ± 21.0	60.3 (24.0–93.0)	0.694
Modified Harris Score	59.2 ± 18.3	60.0 (18.0–91.0)	59.5 ± 18.2	60.0 (18.0–91.0)	56.5 ± 20.0	55.0 (20.0–87.0)	0.630

Table 5
Independent risk factors affecting dislocation.

Pelvic morphologic features	OR (%95 CI)	*p* value
CE° (os)	1.306 (1.026 - 1.663)	**0.030**
CE° (ns)	0.660 (0.469 - 0.931)	**0.018**
OP (Offset Prosthesis)	8.152 (1.087 - 61.124)	**0.041**
FHEI (os)	1.038 (1.006 - 1.071)	**0.020**
TEFHCD (os)	0.095 (0.014 - 0.558)	**0.010**
HHC (ns)	2.020 (1.179 - 3.460)	**0.010**
HHC (os)	0.073 (0.011 - 0.496)	**0.007**

FHEI: Femoral Head Extrusion Index, CE: Center Edge, HHC: Height of Hip Center, TEFHCD: Major Trochanter Upper End and Prosthetic Head Center Distance, (os): Operated Side, (ns): Non-operated Side.

operated side were found to be significant risk factors of dislocation. Patient characteristics and other surgical factors had no effect on the risk of dislocation. Further, the mean postoperative Harris and modified Harris hip scores did not differ between the groups according to the dislocation status.

Several studies reported that the posterior surgical approach in hemiarthroplasty was associated with an increased risk of dislocation, leading to a higher rate of revision surgery, compared with other surgical approaches [9,16,17]. However, some studies emphasized that surgical approach does not affect dislocation risk after hemiarthroplasty [18,11]. Mukka et al. [8] reported a dislocation rate of 10.7%, while Ko et al. [11] reported 1.9% dislocation rate in hemiarthroplasty using a posterior approach with soft tissue repair technique. Most dislocations typically occur within 6 months after hemiarthroplasty surgery [8, 19]. In the present study, we employed a posterior surgical approach to repair the short external rotator tendons and posterior capsule in all cases, the incidence of dislocation was 8.6%, and the mean onset time of dislocation was 2.0 ± 1.1 (range, 1–4) months. All dislocations were in the posterior direction. In the present study, the rate and time of dislocation in hemiarthroplasty was consistent with those previously reported with posterior approach [8,9,16].

Various risk factors for dislocation related to patient or surgery have been identified [8,10–12]. The reported patient-dependent factors were neurological disorders, cognitive dysfunction, abductor muscle weakness, and hip joint deformities [10,20]. Li et al. found that neuromuscular disease and dementia were associated with an increased risk of dislocation [20]. However, Suh et al. found no difference in the incidence of dislocation between patients with or without neuromuscular disease [21]. Kim et al. evaluated the ef-

Table 6
Studies showing dislocation rates after hemiarthroplasty using different surgical approaches.

Study	Approach	Number of dislocated patients n (%)	Associated factors	Outcome
Madanat et al. [22]	Posterolateral	34/602 (5.6%)	Small acetabular coverage, Operation more than 48 h, Longer operation time	Recurrent dislocation in 18 patients (62%)
Varley and Parker[29]	Anterior and posterior	40/1866 (2.1%) in anterior 82/2784 (2.9%) in posterior	Posterior approach has 2 times higher dislocation rate	–
Suh et al. [21]	Posterolateral	5/190 (2.6%) total 2/42 (4.8%) with NMD 3/148 (2.0%) without NMD	No risk factor identified	No recurrence observed
Unwin and Thomas[28]	Lateral and posterior	149/1656 (9%) posterior 41/2150 (3.3%) lateral	–	–
Ninh et al. [12]	Posterior and lateral	6.1% of 174 patients 9 (81.8%) posterior 2 (18.2%) lateral	Age, medical condition, mental disorder, surgical approach and prosthetic malposition	–
Sierra et al. [18]	Anterolateral, posterolateral and transtrochanteric	32/1812 (1.8%)	No significant association with surgical approach	Recurrence in more than half of patients
Barnes et al. [29]	Posterolateral, anterolateral and transtrochanteric	29/1934 (1.5%) total 17 posterolateral approach 12 anterolateral approach	–	25 closed reduction, 13 redislocation
Noon et al. [30]	Lateral	23/612 (4%)	–	Recurrence in 13 patients (57%)
Salem et al. [19]	Anterolateral	27/3525 (0.77%)	Delay in surgery is the most important factor. Closed reduction has high failure rate.	20 patients (76.9%) needed revision surgery
Odumala et al. [31]	Posterior and anterolateral	40/2336 (1.8%) total 35/1836 (1.9%) posterolateral approach 5/500 (1%) anterolateral approach	80% recurrence rate after closed reduction	Significantly high (69%) mortality rate.
Enocson et al. [16]	Anterolateral and posterolateral	45/739 (6%). 39 early and 6 late dislocations 13 (28.9%) anterolateral, 15 (33.4%) posterolateral with repair 17 (37.7%) posterolateral without repair	Posterior repair reduces dislocation rates. Cognitive dysfuncton and dementia increase dislocation risk.	Late dislocation occurred in only posterolateral approach. Closed reduction was successfull in 32/42 patients (76.2%).
Pajarinen et al. [9]	Lateral and posterior	22/338 (7%)	The most important predisposing factor is the use of posterior approach. Residual femoral neck>0.5 cm in patients <165 cm and considerable change in femoral offset are correlated with dislocation	–
Hongisto et al. [27]	Lateral and posterior	4/269 (1.5%) All posterolateral	–	At 1-year, lateral approach group needed more ambulatory aids than posterolateral group
Mukka et al. [32]	Lateral and posterior	24/185 (12.9%). 9 (37.5%) lateral 15 (62.5%) in posterior	–	Direct lateral and posterior approaches have comparable functional outcome after 1 year

NMD: Neuromuscular disease.

fect of patient characteristics on hemiarthroplasty dislocation and reported that age, sex, BMI, comorbidities, ASA score, and mental status did not affect dislocation risk [7]. Correspondingly, Li et al. reported that age, sex, BMI, and comorbidities, including diabetes, chronic pulmonary disease, and heart disease, did not influence dislocation risk [20]. Similarly, Mukka et al. [8] found no differences in age, sex, ASA scores, or mental status between the dislocation group and the remaining cohort. In the present study, we found that neurological disorders such as delirium and dementia do not influence the risk of dislocation. Moreover, age, sex, operation side, ASA score, BMI, and comorbidities such as diabetes, hypercholesterolemia, and thyroid disease had no effect on the risk of dislocation.

Several studies have evaluated the relationship between pelvic morphological features and dislocation in hemiarthroplasty [8,9,11,12,7,22]. Femoral offset, leg length difference, and CE angle have been identified as potential factors affecting the dislocation rates in several recent studies [8,11,12]. Kim et al. [7] found no significant difference in femoral offset and leg length difference; however, they detected a significant difference only in the acetabular CE angle between the dislocation and control groups. A high dislocation rate was seen when the acetabular CE angle was <44. Mukka et al. [8] also reported small CE angle as a risk factor for dislocation, indicating a shallow acetabulum; in addition, they declared that the shortening of the femoral offset and leg length can increase the dislocation rate by decreasing the tension in peripheral soft tissues. Similar to Mukka et al., Madanat et al. [22] and Ninh et al. [12] suggested that shorter femoral offset and smaller CE angle are risk factors for dislocation. Li et al. reported that [20] cup size <43 mm, greater leg length difference, and greater offset difference were associated with an increased risk of dislocation.

In the present study, statistically significant difference was observed in surgical and pelvic morphologic factors including femoral offset, RFNL, TEFHCD, and height of the hip center of the operated side and femoral offset, height of the hip center, and FNSA of the non-operated sides between groups. Moreover, we evaluated the relationship between pelvic morphological features and dislocation in detail. In addition, we determined decreasing offset of the prosthesis and CE angle, and increasing FHEI values as factors that increase the risk of dislocation and increased TEFHCD, Height of the hip center, and CE angle values have protective effects from dislocation. We attributed this to decreased muscle tension associated to the greater trochanter and decreased length of the lever arm, inducing impingement in the hip joint by offset of the prosthesis decrease. Besides, smaller CE angle and higher FHEI rates may cause insufficient coating in the lateral edge of the acetabulum, resulting in dislocation. However, the increase in TEFHCD increases the length of the lever arm and with higher height of the hip center may protect the hip joint from impingement and dislocation.

Several studies showed that excessive residual femoral neck may influence the dislocation rate [9,12]. Pajarinen et al. [9] reported that short patients (height <165 cm) who had a residual femoral neck length >5 mm (OR: 3.0, CI: 0.6–15) tended to have a higher frequency of dislocations than those with a length <5 mm. However Madanat et al. [22] found that patients with dislocation had shorter residual femoral neck (13 mm vs. 16 mm, $p = 0.029$). In our study, we found that RFNL was significantly higher in the dislocation group ($p = 0.013$), but this value was not an independent factor affecting dislocation when binary logistic regression analysis was performed.

Several studies have evaluated the effect of femoral stem type and whether cement is applied or not applied on dislocation after hemiarthroplasty [7,19,23]. Although bipolar hemiarthroplasties appear to have a lower dislocation rate than unipolar hemiarthroplasties, in a meta-analysis of 23,107 patients managed with hemiarthroplasty, after adjustment for the surgical approach and use of cement, no difference in the risk of dislocation was found between unipolar and bipolar hemiarthroplasties [23]. Moreover, several other studies have reported that femoral stem type has no effect on dislocation after hemiarthroplasty [7,19]. There is no clear explanation for the effect of cementation on dislocation, but the use of cemented hemiarthroplasty was described as a possible cause of increased dislocation risk [23]. However Salem et al. [19] reported that the use of a cemented implant was associated with >50% reduction in the risk of dislocation. In our study, we observed that femoral stem type or cement use does not affect dislocation risk.

Dislocation rates after hemiarthroplasty due to femoral neck fracture were reported between 0.8% and 16.7% [24] (Table 6). Posterior approach was reported to be responsible for dislocation. Gill et al. reported lower dislocation rates were reported after the lateral approach [25]. Usually a successful and stable reduction cannot be obtained with the closed reduction in anterior dislocations after lateral approach. However, higher dislocation rates but generally successful closed stable reduction were reported for the posterior approach [25]. Our findings support the finding of Gill et al. In our study, dislocation rate was found high, as 8.6%. All of our patients underwent bipolar hemiarthroplasty through posterior approach. High dislocation rate in our study population may be attributed to posterior approach. Closed reduction attempt was successful in all but one of our patients.

Although with higher dislocation rates, the posterolateral approach has a less negative impact on gait [26]. In addition, patients underwent hemiarthroplasty through the lateral approach needs more ambulatory aids than the posterolateral approach [27]. Controlling the risk factors that were identified in our study would decrease the dislocation rates and be beneficial to postoperative functions and gait of patients.

This study has several limitations. First, this is a retrospective study with a relatively small sample size. Second, lifestyle, job, living alone or not, and mobilization rates were evaluated inadequately, and a version of the prosthesis and fall risk score was not evaluated. These may be influential factors of the varying dislocation rates in addition to anatomic factors. Third, we did not investigate the subgroups of single dislocation and recurrent dislocations; these could have given us more detailed information on the risk of dislocation. Fourth, our study population included patients underwent hemiarthroplasty through posterolateral approach. The measurement parameters might be different in anterior dislocation patients. Detailed prospective studies with larger sample size are needed to determine the effects of factors affecting dislocation after bipolar hemiarthroplasty.

Conclusion

Once the dislocation has occurred, the patient becomes susceptible to various complications and morbidities. Therefore, the clinicians should pay attention to prevent hip dislocation after hemiarthroplasty because conditions such as reduction difficulties, need for open reduction, and increased risk of revision surgery after dislocation may lead to a significant increase in morbidity and mortality. The results of this study suggest that patients with smaller offset of the prosthesis, CE angle of the operated side, and higher FHEI and smaller height of the hip center of the non-operated side should be carefully monitored are these factors are associated with a high incidence of dislocation.

Declaration of Competing Interest

Turan Bilge Kizkapan, Abdulhamit Misir, Erdal Uzun, Sinan Oguzkaya and Mustafa Ozcamdalli declare that they have no actual or potential conflict of interest including any financial, personal, or other relationships with other people or organizations within 3 years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

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