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Low Hand Grip Strength, Mid-Upper Arm Muscle Area, Calf Circumference, Serum Albumin Level, and Muscle Fiber Diameter as Risk Factors for Independent Walking Inability in Patients with Hip Fracture 6 Weeks after Bipolar Hemiarthroplasty Surgery

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Background: Bipolar hemiarthroplasty, one of the main treatment modalities for hip fracture, does not always promise the ability to walk independently after surgery. Patients with the same fracture characteristics and comorbidities, implants, and operators may also have different outcomes. Sarcopenia is thought to be one of the causes of the inability to walk independently after this operation; however, it has not been widely studied and is often overlooked.

Methods: This study used a case-control design with 23 patients in the case group (patients unable to walk independently) and 23 patients in the control group (patients able to walk independently). Sampling was carried out consecutively according to the inclusion and exclusion criteria based on the medical records of patients with hip fractures after bipolar hemiarthroplasty at our hospital. In the preoperative period, hand grip strength (HGS), mid-upper arm muscle area (MUAMA), calf circumference (CC), serum albumin level, and total lymphocyte count were measured. A muscle biopsy was performed intraoperatively from the gluteus muscle with the amount of 200–350 mg. The patient's walking ability was assessed in the polyclinic using the Timed Up and Go test 6 weeks postoperatively. The statistical tests used were descriptive statistics, proportion comparison analysis with the chi-square test, and multiple logistic regression test.

Results: Univariate analysis using chi-square test proved HGS, MUAMA, CC, serum albumin level, and muscle fiber diameter as risk factors for inability to walk independently 6 weeks after bipolar hemiarthroplasty ($p = 0.003$, $p = 0.003$, $p = 0.006$, $p = 0.044$, and $p = 0.000$, respectively). Logistic regression test proved 3 direct risk factors for the inability to walk independently 6 weeks after bipolar hemiarthroplasty, namely MUAMA, serum albumin level, and muscle fiber diameter, as the strongest predictive factor (adjusted odds ratio, 63.12).

Conclusions: Low MUAMA, serum albumin levels, and muscle fiber diameter are direct risk factors for the inability to walk independently in hip fracture patients 6 weeks after bipolar hemiarthroplasty.

Keywords: *Hip fracture, Hemiarthroplasty, Mobility limitation, Sarcopenia*

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Hip fractures affect 18% of women and 6% of men globally, and the incidence doubles with age. Bipolar hemiarthroplasty, as one of the main treatment modalities for hip fracture, does not always promise the ability to walk independently after surgery. Furthermore, the inability to walk independently can also cause complications due to immobilization, such as decubitus ulcers, pneumonia, urinary tract infections, deep vein thrombosis, and death. Patients with the same fracture characteristics and comorbidities and the same implant and operator may also have different postoperative outcomes.

As many as 28% of postoperative hip patients were reported to be unable to walk within 12 months after surgery, and as many as 25%–30% of patients were unable to return to their initial state of mobility. Sarcopenia is thought to be one of the causes of the inability to walk independently after this operation with the prevalence ranging from 5% to 13% in people aged 60–70 years, increasing to 50% in people aged > 80 years;[1] however, the prevalence of sarcopenia in hip fracture patients is largely unknown, and the relationship between sarcopenia and postoperative mobility has not been extensively studied. Therefore, through this study, we intended to determine the risk factors for the inability to walk independently among hip fracture patients after bipolar hemiarthroplasty, particularly related to sarcopenia through clinical, laboratory, and pathology parameters. We hypothesized that hand grip strength (HGS), mid-upper arm muscle area (MUAMA), calf circumference (CC), serum albumin level, and total lymphocyte count (TLC) are risk factors for independent walking inability 6 weeks after bipolar hemiarthroplasty. By knowing these factors, it is hoped that these risk factors can be modified during the perioperative period to maximize postoperative outcomes.

METHODS

This study was approved by the Research Ethics Committee Faculty of Medicine Udayana University, Denpasar, Bali, Indonesia (No. 2881/UN14.2.2.VII.14/LT/2002). Informed consent was not required as our samples were obtained from retrospective data collection from existing medical records, and the researchers did not interact directly with or collect any new data from the patients. However, the individual patient information was anonymized and kept secure to ensure the confidentiality of the medical records.

This study used a case-control design with 23 patients in the case group (patients unable to walk independently) and 23 patients in the control group (patients able to walk independently). Sampling was carried out consecutively according to the inclusion and exclusion criteria based on the medical records of patients with hip fractures after undergoing bipolar hemiarthroplasty at our hospital. Inclusion criteria were as follows: (1) patients aged ≥ 60 years; (2) patients undergoing bipolar hemiarthroplasty at our hospital and coming for 6-week postoperative evaluations in the outpatient department in our hospital; and (3) surgery was performed by a senior orthopedic consultant with minimum 3 years of experience. Exclusion criteria were as follows: (1) incomplete medical records; (2) patients who underwent surgical procedures other than bipolar hemiarthroplasty; (3) patients who underwent bipolar hemiarthroplasty on both hip joints; (4) patients who underwent revision surgery; (5) patients with anatomical abnormalities of the hip and acetabulum; (6) patients with preoperative walking impairments (Koval's grades IV-VII) due to neurological, balance, or other musculoskeletal disorders; (7) patients with abnormal body mass index (BMI; < 18.5 kg/m^2 or > 24.9 kg/m^2); (8) patients with severe comorbidities that may hinder independent walking ability, such as stroke, Parkinson disease, uncontrolled diabetes, kidney failure, tumors, autoimmune diseases, blood clotting disorders, hyperparathyroidism, and hyperthyroidism requiring specific medications; (9) patients with a history of regular immunosuppressive drug consumption; (10) patients with Singh Index 1, 2, or 3, as well as Dorr classification type C.

In the preoperative period, the data of body height, body weight, and BMI were collected and HGS, MUAMA, CC, serum albumin level, and TLC were measured. Koval's grade was also assessed through anamnesis to determine the patient's preoperative ambulatory capacity, where patients with Koval's grades IV-VII were excluded from the study as they were considered housebound.[2]

Hand Grip Strength

HGS measurement was performed using a digital hand dynamometer (Baseline BIMS Digital 5-Position Grip Dynamometer 12-0070 Clinic Model, Fabrication Enterprises Inc.). Each patient was instructed to hold the instrument comfortably in the dominant hand, with the elbow bent at a 90° angle. The patient was then asked to apply maximum grip force to the dynamometer. Three trials were conducted with a 30-second rest interval. The obtained results were averaged and recorded in the tabulation. The HGS measurements were categorized into low (< 26 kg in men and < 18 kg in women) and normal (> 26 kg in men and > 18 kg in women).[2)]

Mid-Upper Arm Muscle Area

Mid arm circumference (MAC) was measured on the dominant arm using a measuring tape at the midpoint between the acromion process and the olecranon. The measurement was taken by placing the tape along the arm's circumference at the marked level, without compressing the underlying tissue. At the same level on the posterior side, triceps skin fold (TSF) was measured. TSF measurement was done by pinching the skinfold using a skinfold caliper (Eiyoken-Type, PAT 376843; Meikosha). MAC and TSF were then used in calculations based on predetermined formulas to determine MUAMA as follows:

$$\text{MUAMC (cm)} = \text{MAC (cm)} - 0.314 \times \text{TSF (mm)}$$

$$\text{MUAMA} = \frac{\text{MUAMA}^2}{4\pi}$$

The MUAMA measurements were categorized into low (< 32 cm^2 in men and < 18 cm^2 in women) and normal (> 32 cm^2 in men and > 18 cm^2 in women).[3)]

Calf Circumference

CC was measured by measuring the circumference of the healthy calf in the area with the largest diameter using a measurement tape. The CC measurements were categorized into low (< 34 cm in men and < 29 cm in women) and normal (> 34 cm in men and > 29 cm in women).[2)]

Serum Albumin Level

The assessment of serum albumin levels was obtained from the patient's blood samples. The results of the serum albumin measurements are presented as numerical data obtained through laboratory examination using the Bromocresol green technique. The albumin levels were categorized as low if they were < 3.5 g/dL and normal if > 3.5 g/dL.[4)]

Total Lymphocyte Count

The assessment of TLC was obtained from patients' blood samples. The results are presented as numerical data. It was calculated through a leukogram using the percentage of lymphocytes and the absolute lymphocyte count (number of lymphocytes per microliter of blood). The TLC was categorized as low if it was < 1,500 cells per mm^3 of blood and considered normal if it was > 1,500 cells/mm^3 of blood.

Fracture Diagnosis

The diagnosis of fractures was established through clinical examinations and radiological assessments, including anteroposterior (AP) pelvic X-ray and AP and lateral X-rays of the femur. Subsequently, the Singh Index was measured based on the proximal femur trabeculation, and the Dorr classification was determined. Patients with a Singh Index of 1, 2, or 3 were not included in the study due to the presence of osteoporosis. Likewise, patients with Dorr classification type C were also excluded from the study.

Surgical Technique and Muscle Fiber Diameter Assessment

The surgical technique used in this study involved bipolar hemiarthroplasty (cementless as well as cemented). The surgeries were performed by senior orthopedic surgeons in our hospital with a minimum of 3 years of experience in the field (IWSD, IGNWA, CGOD, and IWS). During the surgical procedure, muscle biopsies were taken from the gluteus muscle, amounting to 200–350 mg (approximately 0.5 × 1 cm in size). The gluteus muscle was technically exposed during the surgical procedure, ensuring that the sampling did not damage a broader area of soft tissue.

The biopsied muscle was then fixed in 4% paraformaldehyde for 24 hours. To preserve the sample, liquid nitrogen was used to freeze the biopsied sample immediately after excision and the storage temperature was maintained at −80 °C until analysis. The sample then underwent an alcohol dehydration process, preparation in paraffin blocks, trimming, and water bathing process. Sections of 3-μm thickness were stained with hematoxylin and eosin. To assess muscle fiber atrophy, a minimum of 200 muscle fibers per biopsy were evaluated under a light microscope at magnifications of ×10, ×40, and ×100. Their diameters were measured and averaged using cellSens Standard software (Olympus). Muscle fibers with a diameter < 30 μm indicate sarcopenia.[5)]

Postoperative Care and Timed Up and Go Test

In the postoperative period, all patients received the same

treatment in terms of wound care, nutrition as provided by a nutrition specialist, and standard rehabilitation protocols by medical rehabilitation and a physiotherapy team. The physiotherapist dedicated 30–60 minutes each day to working with the patients to help them regain mobility starting on the first day after surgery. The physical therapy regimen included exercises to support weight-bearing, enhance muscle strength, improve walking ability, and advance functional skills based on each patients unique level of functionality. Occupational therapy focused on instructing patients in activities of daily living, which encompassed tasks like transferring, standing from a sitting position, moving in bed, getting dressed, and self-care retraining. Various mobility aids such as canes, crutches, wheeled walkers, and gait trainers were employed during these mobility exercises. During the postoperative care period in the outpatient department, the patients' walking ability was assessed using the Timed Up and Go Test (TUG) at 6 weeks after the surgery. TUG was conducted by measuring the time taken for the patient to stand up from a chair (45-cm high), walk 3 meters as quickly and safely as possible, return to the chair, and sit down. During the test, patients were not allowed to use walking aids.

Statistical Analysis

After all the data were collected, tabulations were created, and the relevant risk factors were analyzed using the statistical software program SPSS for Windows (ver. 24, IBM Corp.). Descriptive statistical analysis was conducted to describe the characteristics of the subjects and research variables according to the case and control groups. Subsequently, a comparison of proportions analysis was performed for each independent variable. This analysis was carried out by creating 2 × 2 cross-tabulations and calculating the measure of association in the form of odds ratio (OR).

For unpaired categorical comparative data with 2 × 2 cross-tabulations and meeting the chi-square requirements, the chi-square test with Yates correction was used. If the x^2 requirements were not met, Fisher's exact test was utilized. Furthermore, multivariate analysis was conducted to assess the risk factors for the inability to walk independently 6 weeks after bipolar hemiarthroplasty. This analysis involved including all significant independent variables and evaluating their impact on the dependent variable. The measure of association obtained was the adjusted OR (AOR). The significance level (α) for this study was set at $p < 0.05$.

RESULTS

Descriptive Analysis

From the descriptive analysis, it was found that there were 46 samples (23 patients capable of independent walking and 23 patients unable to walk independently at 6 weeks after bipolar hemiarthroplasty), with an average age of 72.46 ± 8.98 years. Categorically, the age range of 60–70 years had the highest frequency, comprising 22 patients (47.8%). The number of women was higher than men, with a male-to-female ratio of 9 (19.6%) to 37 (80.4%). BMI of the patients was all within normal range (18.75–24.725 kg/m^2), with a mean of 22.4 kg/m^2. The preoperative ambulatory capacity of the patients as defined by Koval's grade was mostly grade I (52.17%), followed by grade II (32.6%) and grade III (15.23%). In terms of fracture type, the majority were femoral neck fractures, followed by intertrochanteric femur and pertrochanteric femur fractures (82.6%, 15.2%, and 2.2%, respectively). The right side was slightly more commonly affected than the left side (52.2% vs. 47.8%). Most patients were classified as Dorr type B (58.7%), and cementless implants were more commonly used (58.7%).

Among the various risk factors studied, the average HGS was 16.9 ± 5.15 kg, with a majority of patients having low HGS (71.7%). Meanwhile, the mean MUAMA in the group capable of independent walking was 23.78 ± 4.83 cm^2, with most having a normal MUAMA (60.9%). Another clinical parameter examined was CC, with an overall average of 28.6 ± 2.99 cm, and the majority of samples had low CC (63%). The laboratory parameters studied were serum albumin levels and TLC, with average values of 3.07 ± 0.78 g/dL (low in 72.9%) and 1,358.91 ± 652.824 cells/mm^3 (low in 67.4%), respectively. The last risk factor examined was muscle fiber diameter, with an average of 39.52 ± 12.42 μm, with a majority of patients having normal muscle fiber diameter (69.6%). Table 1 shows the characteristics of patients included in the study.

Further analysis was performed on the basic characteristics of the research subjects that could potentially affect the results (confounding variables). Chi-square analysis was performed for age, fracture type, hip side, Dorr classification, and implant type variables, while Fisher's Exact test was used for the sex variable. The results showed that there were no significant differences between the 2 groups in terms of age, sex, fracture type, hip side, Dorr classification, and implant type (Table 1). Hence, we concluded that these variables were not confounding factors in the study.

Table 1. Characteristics of Patients in the Study and Inferential Analysis Results for Potential Risk Factors of Independent Walking Inability

Variable	Mean ± SD	Case group (unable to walk independently) (n = 23)	Control group (able to walk independently) (n = 23)	*p*-value	OR (95% CI)
Age (yr)	72.5 ± 9.0			0.549	
60–70		12 (52.2)	10 (43.5)		
71–80		7 (30.4)	5 (21.7)		
81–90		3 (13)	7 (30.4)		
> 90		1 (4.3)	1 (4.3)		
Sex				1.000	
Male		5 (21.7)	4 (17.4)		
Female		18 (78.3	19 (82.6)		
Fracture type				0.063	
Neck femur		22 (95.7)	16 (69.6)		
Intertrochanter femur		1 (4.3)	6 (26.1)		
Pertrochanteric femur		0	1 (4.3)		
Hip side				0.555	
Right		13 (56.5)	11 (47.8)		
Left		10 (43.5)	12 (52.5)		
Dorr classification				0.369	
A		11 (47.8)	8 (34.8)		
B		12 (52.5)	15 (65.2)		
Implant type				0.134	
Cementless		16 (69.6)	11 (47.8)		
Cemented		7 (30.4)	12 (52.2)		
Hand grip strength (kg)	16.90 ± 5.15			0.003	9.625 (1.821–50.886)
Normal		21 (91.3)	12 (52.2)		
Low		2 (8.7)	11 (47.8)		
MUAMA (cm^2)	23.78 ± 4.83			0.003	7.389 (1.887–28.939)
Normal		14 (60.9)	4 (17.4)		
Low		9 (39.1)	19 (82.6)		
CC (cm)	28.60 ± 2.99			0.006	6.175 (1.589–23.993)
Normal		19 (82.6)	10 (43.5)		
Low		4 (17.4)	13 (56.5)		
Albumin serum level (g/dL)	3.07 ± 0.78			0.044	4.286 (0.981–18.721)
Normal		20 (87)	14 (60.9)		
Low		3 (13.0)	9 (39.1)		

Table 1. Continued

Variable	Mean ± SD	Case group (unable to walk independently) (n = 23)	Control group (able to walk independently) (n = 23)	*p*-value	OR (95% CI)
Total lymphocyte count (cells/mm^3)	1,358.91 ± 652.82			0.345	
Normal		17 (73.9)	14 (60.9)		
Low		6 (26.1)	9 (39.1)		
Muscle fiber diameter (μm)	39.52 ± 12.42			0.000	28.600 (3.275–249.726)
Normal		10 (43.5)	22 (95.7)		
Low		13 (56.5)	1 (4.3)		

Age, sex, fracture type, hip side, Dorr classification, and implant type were not proven as confounding variables. Hand grip strength, MUAMA, CC, serum albumin level, and muscle fiber diameter were identified as significant risk factors; however, total lymphocyte count was not proven as risk factor.
SD: standard deviation, OR: odds ratio, CI: confidence interval, MUAMA: mid-upper arm muscle area, CC: calf circumference.

Hand Grip Strength

Chi-square analysis proved low HGS as a significant risk factor for the inability to walk independently 6 weeks after bipolar hemiarthroplasty surgery, with a statistically significant difference ($p = 0.003$, $p < 0.05$). Further analysis revealed an OR of 9.625 (95% confidence interval, 1.821–50.886), indicating that patients with low HGS have a 9.625 times higher likelihood of being unable to walk independently 6 weeks after bipolar hemiarthroplasty surgery compared to patients with normal HGS (Table 1).

Mid-Upper Arm Muscle Area

Chi square analysis indicated that having a low MUAMA was a significant risk factor for the inability to walk independently after 6 weeks of bipolar hemiarthroplasty, with a statistically significant difference ($p = 0.003$). Further analysis revealed that patients with low MUAMA had 7.389 times higher likelihood of being unable to walk independently at 6 weeks after surgery compared to patients with normal MUAMA (Table 1).

Calf Circumference

As shown in Table 1, it was proven that having a low CC was a significant risk factor for the inability to walk independently after 6 weeks of bipolar hemiarthroplasty, with a statistically significant difference ($p = 0.006$). Further analysis revealed that patients with low CC had 6.175 times higher likelihood of being unable to walk independently at 6 weeks after surgery compared to patients with normal CC.

Serum Albumin Level

In terms of serum albumin level, low level of albumin was proven as a significant risk factor for the inability to walk independently after 6 weeks of bipolar hemiarthroplasty, with a statistically significant difference ($p = 0.044$). Further analysis revealed that patients with low albumin levels had 4.286 times higher likelihood of being unable to walk independently at 6 weeks after surgery compared to patients with normal albumin levels (Table 1).

Total Lymphocyte Count

Through Table 1, it was shown that having a low TLC is not a risk factor for the inability to walk independently at 6 weeks after bipolar hemiarthroplasty surgery, with no statistically significant difference ($p = 0.345$, $p > 0.05$). Therefore, patients with low TLC are not at a higher risk of experiencing the inability to walk independently at 6 weeks after surgery compared to patients with normal TLC.

Muscle Fiber Diameter

Chi-square analysis showed that low muscle fiber diameter is a significant risk factor for the inability to walk independently after 6 weeks of bipolar hemiarthroplasty, with a statistically significant difference ($p < 0.001$). Further analysis revealed an OR of 28.6 (95% CI, 3.275–249.726), suggesting that patients with low muscle fiber diameter are 28.6 times more likely to experience difficulty in walking independently 6 weeks after bipolar hemiarthroplasty compared to those with normal muscle fiber diameter (Table 1). Fig. 1 shows an example of muscle fiber diameter analysis histopathologically.

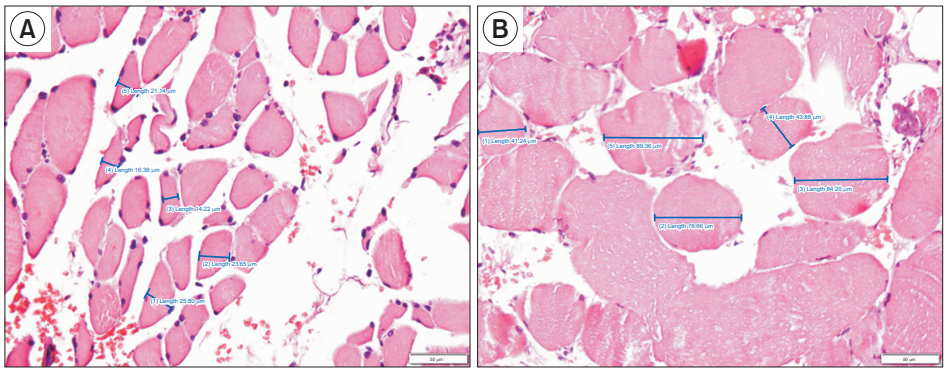

Fig. 1. Example of muscle fiber diameter examination results after hematoxylin and eosin staining under ×100 magnification, showing small muscle fiber diameter (A) and normal muscle fiber diameter (B).

Table 2. Logistic Regression Analysis to Identify Direct Risk Factors for Impaired Walking Ability in Hip Fracture Patients 6 Weeks after Bipolar Hemiarthroplasty

Risk factor	*p*-value	Exp(B)	95% CI for Exp(B)
Hand grip strength	0.071	13.961	0.801–243.236
MUAMA	0.027	15.72	1.359–181.777
CC	0.979	0.974	0.128–7.389
Serum albumin level	0.028	24.348	1.401–423.232
Muscle fiber diameter	0.019	63.12	1.969–2,023.241

MUAMA, serum albumin level, and muscle fiber diameter were the strongest predictive factors.
CI: confidence interval, MUAMA: mid-upper arm muscle area, CC: calf circumference.

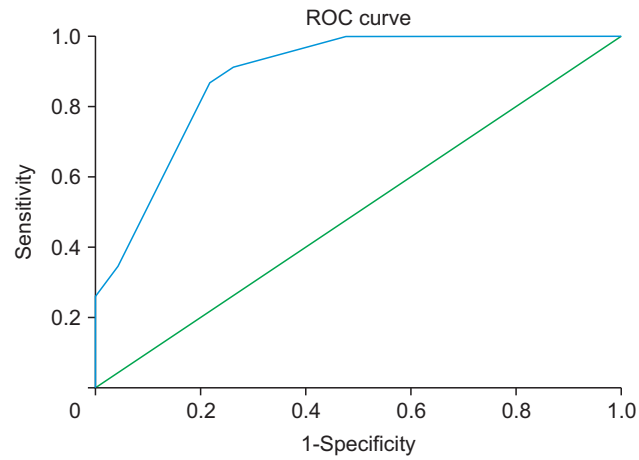

Fig. 2. Receiver operating characteristic (ROC) curve of discrimination test. The discrimination test using the ROC curve yielded an area under the curve value of 88.8% (95% confidence interval, 0.792–0.983).

MUAMA, Albumin Serum Level, and Muscle Fiber Diameter as Direct Risk Factors for Independent Walking Inability

From Table 2, it can be observed that in the multivariate analysis, the variables that have a direct effect on independent walking inability in hip fracture patients 6 weeks after bipolar hemiarthroplasty are low MUAMA, preoperative serum albumin level, and muscle fiber diameter. The strength of these relationships is indicated by the AOR (EXP(B)) values, where muscle fiber diameter has the strongest association (AOR, 63.12), and the weakest association was CC (AOR, 0.974), followed by HGS (AOR, 13.961), and MUAMA (AOR, 15.72).

The logistic regression analysis underwent calibration testing using the Hosmer and Lemeshow test and discrimination testing using the receiver operating characteristic curve. The Hosmer and Lemeshow test yielded a *p*-value of 0.986 ($p \geq 0.05$) in step 2, indicating that the obtained equation was well-calibrated. The discrimination test resulted in an area under the curve value of 88.8% (95% confidence interval [CI], 0.792–0.983) (Fig. 2), indicating a strong accuracy of the regression equation (80%–90%).

The logistic regression equation obtained from the analysis is as follows: Y = −6.315 + 2.745 (MUAMA) + 3.192 (albumin) + 4.131 (fiber diameter). MUAMA, serum albumin level, and fiber diameter are given a value of 1 when low and a value of 0 when normal. From this equation, the probability of impaired walking ability 6 weeks after bipolar hemiarthroplasty can be calculated using the formula: $p = 1/(1+e^{-y})$, where *p* is the probability, e is the natural number (2.7), and y is the result of the logistic regression equation (3.753).

Using the formula, it was found that if MUAMA, serum albumin level, and fiber diameter are low, the probability of impaired walking ability 6 weeks after bipolar hemiarthroplasty surgery is 97.65%. Table 3 shows the probabilities of impaired walking ability based on the various clinical conditions that may be encountered in practice.

Table 3. The Probability of Independent Walking Inability Based on the Parameters of MUAMA, Serum Albumin Level, and Muscle Fiber Diameter

No.	MUAMA	Albumin	Muscle fiber diameter	Probability of independent walking inability (%)
1	Low	Low	Low	97.65
2	Normal	Low	Low	73.13
3	Low	Normal	Low	63.58
4	Low	Low	Normal	40.72
5	Normal	Normal	Low	10.25
6	Normal	Low	Normal	4.30
7	Low	Normal	Normal	2.80
8	Normal	Normal	Normal	0.19

The probability of impaired walking ability was 97.65% when the 3 factors were identified.
MUAMA: mid-upper arm muscle area.

DISCUSSION

Internal and external factors were predicted to affect independent walking ability in patients with hip fracture after bipolar hemiarthroplasty. Regarding sex, a previous study by Holt et al.[6] stated that female patients with hip fractures were 1.25 times more likely to regain their independent mobility compared to male patients. Additionally, male patients also had a higher risk of mortality within 30 and 120 days after hip fracture surgery.[6] However, the results of our study were similar to those of Kristensen et al.,[7] which found that sex did not affect the walking ability of hip fracture patients ($p = 1.0$).[7] Regarding age, it was generally assumed that walking ability would worsen with increasing age. However, this was not supported by our study's findings. A study by Hagino et al.[8] reported that 78.4%–90.5% of patients under 85 years of age could walk independently after hip surgery, compared to only 41.7%–64.8% of patients over 85 years old, with a statistically significant difference ($p < 0.0005$).[8] On the other hand, the findings in our study were in line with those of Haentjens et al.,[9] which found that age was not a risk factor for the inability to walk independently after hip fracture surgery ($p = 0.133$). They further stated that older patients tend to have more complex comorbidities and poorer baseline health status, potentially leading to bias in other studies with different results.[9]

Most of the literature suggests that patients with neck femur fractures tend to have better postoperative outcomes compared to patients with trochanteric fractures. A study by Haentjens et al.[9] stated that the type of fracture has an impact on short-term patient mobility; patients with intertrochanteric fractures have lower independent walking ability. However, this was not found in the long-term observation (6 months). It was further mentioned that potential bias could be caused by differences in rehabilitation strategies between facilities.[9] Kristensen et al.[10] also stated that intertrochanteric fractures cause larger muscle edema, resulting in more severe pain and lower knee extension strength.

However, a study in 2016 by Mariconda et al.[11] proved otherwise. In their study, it was stated that the type of fracture was not shown to be a predictor of postoperative functional outcomes in hip fracture patients. Furthermore, they found that these outcome differences were not significant even up to 1 year after the surgery. Possible factors contributing to bias could be the variation in pre-trauma functional status and poor pre-fracture health conditions among patients with trochanteric fractures.[11]

Both cemented and cementless implant types were included in this study, with the chi-square test showing no significance as a confounding variable. This was further supported by the study conducted by Nantha Kumar et al.,[12] which stated that there were no significant differences in terms of functional outcomes, pain, walking ability, complications, and long-term quality of life between the use of cementless and cemented implants. Three of our patients with femoral intertrochanteric fractures were treated with long stem implants, though it was doubted that it would serve as a confounding variable. A study by Sousa et al.[13] demonstrated that there were no significant differences in terms of functional clinical outcomes between arthroplasty using long and standard stem implants. The only difference found was that patients with long stem implants more frequently complained of thigh pain, which is believed to be related to the implant design and stiffness. Long stem implants have a much higher modulus of elasticity compared to the cortical bone's modulus of elasticity. As a result, in patients with standard stem implants, the femoral elasticity remains preserved, and the occurrence of thigh pain can be avoided.[13]

The first risk factor analyzed was low HGS. It reflects poor muscle strength and is associated with sarcopenia, as patients with normal HGS have a greater positive effect on rehabilitation outcomes. This is supported by another study by Selakovic et al.[14] which demonstrated that HGS has a high prognostic value for independent walking ability after hip fracture surgery, especially when assessed in the acute condition (due to muscle mass re-

duction caused by decreased mobilization > 10 days after hip fracture). Additionally, HGS is an easy, cost-effective, and simple examination to be routinely applied in patients with limited mobility in daily clinical practice.[14] In this study, we emphasized the importance of assessing HGS in postoperative mobilization exercises, especially during the early rehabilitation phase when patients undergoing bipolar hemiarthroplasty typically have to use a walker. Having a normal grip strength is crucial in facilitating the walking training process.

In general, MUAMA is considered an inexpensive and easily performed method for screening anthropometry, especially in developing countries. However, to date, studies on the role of MUAMA measurement in patients with hip fractures are still very limited. Studies by Tartari et al.[15] and Wallengren et al.[16] demonstrated that MUAMA is one of the indicators of muscle mass measurement that has potential prognostic factors for survival and quality of life in elderly patients, especially those undergoing palliative care. However, this is in contrast to the study by Rodriguez-Bocanegra et al.,[17] which showed that there was no significant difference in the average upper arm diameter between patients who could and could not walk within 4 days after hip fracture surgery ($p = 0.731$).

In our study, we chose the measurement of CC to reflect lower extremity muscle mass. Regarding CC, a study by Chen et al.[1] has demonstrated the accuracy of CC measurements with a sensitivity of 88.4% and specificity of 72.7% in detecting sarcopenia. Additionally, CC has been shown to be associated with quality of life, functional impairments, length of hospital stay, and mobility in elderly patients.[1] Another study by Borges et al.[18] also demonstrated that 30% of patients with hip fractures suffer from sarcopenia, and CC is considered the most relevant predictive model for these patients. However, this contradicts a previous study by Rodriguez-Bocanegra et al.,[17] which found no significant difference in CC among patients after hip fracture surgery, concerning their ability for short-term sitting and walking mobility during hospitalization. Furthermore, there are discrepancies in the cutoff values reported in various studies. For instance, Chen et al.[1] used a cutoff of < 34 cm for men and < 33 cm for women to diagnose sarcopenia, while Mienche et al.[2] used a cutoff of < 34 cm for men and < 29 cm for women. In our study, the cutoff values according to Mienche et al.[2] were utilized due to the similarity in sample characteristics and the location of the research, which was also conducted in Indonesia.

In the study by Sim et al.,[19] it is explained that serum albumin serves as a marker of health and nutrition status. Low albumin levels hinder fracture and bone healing and impede the recovery of neuromuscular function, further leading to an increased risk of complications.[19] However, the findings of this study are inconsistent with the research by Landi et al.,[20] which demonstrated that there was no significant difference in albumin levels between patients with hip fractures who had sarcopenia and those who did not ($p = 0.68$). Regarding the management, a study by Nakahara et al.[21] supports nutritional interventions, such as a protein intake of around 1.2 g/kg BW/day, for patients with hip fractures to address hypoalbuminemia and improve muscle mass. However, it is noted that nutritional therapy alone may not lead to optimal functional outcomes if not combined with aggressive rehabilitation and physical exercises during the postoperative period.[21]

The only factor that was not proven to increase the risk of impaired independent walking ability after surgery is the TLC. Research by Hong et al.[22] stated that the level of lymphocytes in the serum reflects the immune status of patients with hip fractures, and low lymphocyte levels are associated with higher postoperative complication rates in these patients. However, several conditions were said to be possible factors influencing abnormal lymphocyte levels, including coronary heart disease, hypertension, ischemic stroke, chronic kidney disease, diabetes mellitus, cancer, and peripheral artery disease.[22]

Optimal muscle fiber diameter is considered important for generating strength during muscle contractions, and it is therefore related to the ability to maintain body posture during walking exercises. A study by Sato et al.,[23] which used muscle biopsies from gluteal muscles of elderly patients with hip fractures, stated that the reduction in muscle fiber diameter in these patients could be attributed to several factors, such as the aging process, prolonged immobilization with traction during the preoperative period, and low levels of physical activity before the trauma. Consequently, having a smaller muscle fiber diameter may contribute to the occurrence of hip fractures and vice versa (hip fractures may lead to reduced muscle fiber diameter). The diminishment of muscle fiber diameter results in weakened supporting tissues around the hip joint, increasing the likelihood of falls during the pretrauma period and hindering the process of physical rehabilitation, ultimately leading to poor functional outcomes and walking ability during the postoperative period.[23] Additionally, Testa et al.[24] stated that histological evaluation of muscle fiber diameter is one of the accurate diagnostic methods for sarcopenia, although it is rarely performed routinely in everyday practice. On the other hand, Shin et

al.[25] found evidence to the contrary, showing that sarcopenia is not associated with functional outcomes or mobility in patients with hip fractures. A systematic review by Testa et al.[24] on sarcopenia in patients with hip fractures stated that the establishment of sarcopenia diagnosis is still uncertain, and there is no optimal diagnostic tool yet. However, they suggested that a combination of clinical and supportive tests could enhance the accuracy of sarcopenia diagnosis.[24] The brief summary of the key findings of our study and its comparison with previous studies is shown in Table 4.

This study has limitations, such as the absence of Skeletal Muscle Index examination, which is not routinely utilized in our hospital. However, we performed appropriate anthropometric assessment and control through exclusion criteria to minimize possible bias caused by obesity or underweight condition. To our knowledge, this study is the first to investigate sarcopenia and identify key risk factors associated with a patient's ability to regain independent walking after hip fracture surgery from 3 aspects

Table 4. Comparison with Previous Studies Related to the Key Findings of This Study

Risk factor	This study	Previous study	Study lacking
HGS	Low HGS is a significant risk factor for the inability to walk independently 6 weeks after bipolar hemiarthroplasty (p = 0.003; OR, 9.625).	Selakovic et al. (2019)[14]: HGS has a high prognostic value for functional outcome after hip fracture surgery, especially when assessed in the acute condition.	No previous study regarding the effect of HGS, especially on postoperative walking ability
MUAMA	Low MUAMA is a significant risk factor for the inability to walk independently after 6 weeks of bipolar hemiarthroplasty (p = 0.003; OR, 7.389).	Rodriguez-Bocanegra et al. (2020)[17]: no significant difference in the average upper arm diameter between patients who could and could not walk within 4 days after hip fracture surgery.	No previous study proving MUAMA as risk factor for impaired walking ability in patients with hip fracture
CC	Low CC is a significant risk factor for the inability to walk independently after 6 weeks of bipolar hemiarthroplasty (p = 0.006; OR, 6.175).	Chen et al. (2020)[1]: CC is associated with quality of life, functional impairment, duration of care, and mobility in elderly patients. Rodriguez-Bocanegra et al. (2020)[17]: no significant difference in terms of CC among postoperative hip fracture patients, related to short-term sitting and walking mobility during the hospitalization period.	Previous study proving CC as risk factor was performed in general elderly population, not specifically in patients with hip fractures. Another study observed only in short period during hospitalization.
Serum albumin level	Low serum albumin level is a significant risk factor for the inability to walk independently after 6 weeks of bipolar hemiarthroplasty (p = 0.044; OR, 4.286).	Sim et al. (2021)[19]: hypoalbuminemia is an independent risk factor for poor postoperative walking ability and worse quality of life in patients undergoing hip surgery, as measured by Harris Hip Score, Parker Mobility Scale, and SF-36 Survey. Landi et al. (2017)[20]: no significant difference in albumin levels between hip fracture patients with low and normal muscle mass (but no analysis in correlations between hypoalbuminemia and mobility).	Controversial results and insufficient amount of study regarding the correlations between hypoalbuminemia and mobility
TLC	Low TLC is not a risk factor for the inability to walk independently at 6 weeks after bipolar hemiarthroplasty (p = 0.345).	Hong et al. (2023)[22]: TLC reflects the immune status of patients with hip fractures and are associated with higher postoperative complication rates.	No study specifically discusses the relation of TLC with walking ability.
Muscle fiber diameter	Low muscle fiber diameter is a risk factor for the inability to walk independently after 6 weeks of bipolar hemiarthroplasty (p = 0.000; OR, 28.6)	Sato et al. (2002)[23]: low muscle fiber diameter hinders the process of physical rehabilitation, ultimately leading to poor functional outcomes and walking ability during the postoperative period. Shin et al. (2020)[25]: sarcopenia is not associated with functional outcomes or mobility in patients with hip fractures.	Controversial previous studies and insufficient amount of recent studies utilizing histopathology result from muscle biopsy and its correlation with postoperative walking ability
Multivariate analysis	Low MUAMA, serum albumin level, and muscle fiber diameter have direct effect, with 97.65% probability of impaired walking ability 6 weeks after bipolar hemiarthroplasty if the 3 factors are observed simultaneously.	Testa et al. (2020)[24]: the establishment of sarcopenia diagnosis is still uncertain, and there is no optimal diagnostic tool yet.	No previous study analyzing the combination of clinical and supportive tests to enhance the accuracy of sarcopenia diagnosis and its relationship with postoperative mobility

HGS: hand grip strength, OR: odds ratio, MUAMA: mid-upper arm muscle area, CC: calf circumference, SF-36: 36-item short form health survey, TLC: total lymphocyte count.

of diagnosis simultaneously: clinical, laboratory, and histopathological. It is hoped that these findings can guide tailored multidisciplinary rehabilitation programs, including targeted exercises and nutritional interventions, to improve outcomes. Future research should explore interventions to address these risk factors and enhance mobility for hip fracture patients with the possible utilization of personalized postoperative care programs and technology integration.

Low HGS, MUAMA, CC, serum albumin levels, and muscle fiber diameter were risk factors for inability to walk independently in hip fracture patients 6 weeks after bipolar hemiarthroplasty surgery, whereas a low TLC was not proven as a risk factor. In addition, when MUAMA, serum albumin level, and fiber diameter were low, the probability of impaired walking ability 6 weeks after bipolar hemiarthroplasty surgery was 97.65%.

CONFLICT OF INTEREST

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

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