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Original article

Relationship between the perioperative prognostic nutritional index and postoperative gait function in elderly hip fractures

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ABSTRACT

Objectives: We investigated the relationship between the perioperative nutritional status and postoperative walking ability in patients with hip fractures.
Methods: We included 246 surgically treated elderly patients with hip fractures who were ambulatory before the injury. Patients were divided into two groups: group A, who were able to walk at discharge, and group B, who were unable to walk at discharge. We pair-matched these two groups according to age, preoperative subdivided walking ability, and fracture site to form groups A′ and B’. The prognostic nutritional index (PNI; PNI = 10 × serum albumin (g/dL) + 0.005 × blood total lymphocyte count (/mm^3)) before surgery and 1 day, 1 week, and 2 weeks after surgery and energy intake 1 and 2 weeks after surgery were compared.
Results: After adjustments for age, preoperative subdivided walking ability, and fracture site, there were 51 patients in group A’ (mean age 84.6 years) and 51 patients in group B’ (mean age 84.7 years). In group A’/group B′, PNI was 43.38/42.60 (P = 0.19) before surgery, 33.87/33.31 (P = 0.44) 1 day after surgery, 34.99/32.35 (P = 0.01) 1 week after surgery, and 37.33/35.69 (P = 0.15) 2 weeks after surgery. Energy intake was 1380.8/1203.1 kcal (P = 0.01) 1 week after surgery and 1382.0/1335.6 kcal (P = 0.60) 2 weeks after surgery.
Conclusions: PNI and energy intake at 1 week postoperatively were associated with early postoperative nutrition and the recovery of walking ability.

1. Introduction

Malnutrition is common in older hip fracture patients and is associated with reduced muscle strength, increased postoperative complications, and mortality [1,2]. Approximately 60% of hip fracture patients were previously reported to be malnourished on admission [3]. The prognostic nutritional index (PNI) is a measure of the nutritional status that is easy to calculate from serum albumin levels and the total lymphocyte count [4]. A recent study indicated the potential of PNI as a predictor of perioperative complications in orthopedic surgery [5]. In patients with fragile hip fractures, preoperative PNI was associated with postoperative delirium [6,7], surgical site infections (SSI) [8], death within two years, and postoperative complications [9].

Only 14% of all patients are adequately nourished during their stay in acute care hospitals [10]. Aggressive exercise therapy under a low nutritional status or inadequate nutritional management may result in malnutrition, progressive muscle weakness, and endurance loss due to increased protein catabolism caused by energy deficiency; therefore, nutritional therapy needs to be prioritized over exercise therapy in patients with a low nutritional status [11]. Regarding the relationship between the perioperative nutritional status and motor function, preoperative malnutrition has been associated with a reduced walking ability 6 months after surgery and the Harris Hip Score from 3 months after surgery [12,13]. However, limited information is currently available on the relationship between the perioperative nutritional status and walking ability in the early postoperative period [14].

Exercise therapy in the early postoperative period is important for elderly patients with hip fractures. However, these patients may not have sufficient energy intake for gait training in the perioperative period, which may reduce the effectiveness of gait training in the early postoperative period. Therefore, we considered it necessary to examine the perioperative energy intake and nutritional status of patients

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undergoing hip fracture surgery and their relationship with the recovery of walking ability. Therefore, the present study investigated the relationship between the perioperative nutritional status and early postoperative walking ability in patients undergoing hip fracture surgery in an acute care hospital. The relationship between energy intake and PNI up to 2 weeks after surgery and walking ability at discharge from our hospital was also analyzed.

2. Methods

A retrospective observational study based on electronic medical record entries was conducted. Of 274 patients with hip fractures operated on in our department between January and December 2021, 246 (mean age 83.0 ± 9.6 years, 64 males and 182 females) who were able to walk before their injury were included. PNI was calculated from serum albumin levels and blood total lymphocyte counts before surgery and 1 day, 1 week, and 2 weeks after surgery (PNI = 10 × serum albumin (g/dL) + 0.005 × blood total lymphocyte count (/mm^3)). We also retrospectively analyzed dietary menus and food intake rates in medical records and calculated oral energy intakes 1 and 2 weeks after surgery.

Patients were divided into two groups: 117 patients in group A who were able to walk using a T-cane or walker at the time of discharge from the hospital, and 129 patients in group B who were unable to walk and were discharged by wheelchair transfer. The number of days in the hospital, PNI (before surgery and 1 day, 1 week, and 2 weeks after surgery), and energy intake (1 and 2 weeks after surgery) were compared as endpoints. Fracture site (femoral neck fracture or femoral trochanteric fracture) and subdivided preoperative walking ability (able to walk outdoors, able to walk indoors without aids, or needing aids such as cane or walker for indoor walking), surgical method (open reduction and internal fixation, ORIF or bipolar hip arthroplasty, BHA), postoperative unloading (full load allowed from the day after surgery or postoperative unloading period required) and preoperative blood test data (brain natriuretic peptide, BNP; estimated glomerular filtration rate, eGFR; HbA1c) were also examined retrospectively using electronic medical record data.

In addition, we pair-matched these two groups according to age, preoperative subdivided walking ability, and fracture site to form groups A′ and B′, and were compared for the same endpoints.

The statistical analysis software EZR Version 1.55 was used and the Mann-Whitney *U* test was performed [15]. The significance level was set at 0.05. Receiver operating characteristic curves were generated to select the optimal cut-off values for PNI before surgery and 1 and 2 weeks after surgery in patients who were able to walk at the time of discharge from our hospital.

This study was approved by the Iwata City Hospital Ethical Review Committee (number: 2022-015) following the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. In addition, anonymity was ensured for all patients and their families who participated in this study, and no names nor addresses were issued that could help identify these individuals. Informed consent was obtained from all individual participants included in the study. Since this was a retrospective study, we performed an opt-out procedure to guarantee participants the right to withdraw from the study at any time.

3. Results

The mean age of 117 patients in group A (31 males, 86 females) was 79.5 ± 10.6 years and that of 129 patients in group B (33 males, 96 females) was 86.1 ± 7.4 years, with group B being significantly older than group A ($P < 0.001$) (Table 1). When preoperative walking ability was subdivided, in group A, 75.2% could walk outdoors, 16.2% could walk indoors without aids, and 0.09% needed aids such as a cane or walker to walk indoors; in group B, 29.5%, 45.0%, and 25.6%, respectively. In group A, 36/117 (30.8%) had femoral trochanteric fractures and 81/117 (69.2%) had femoral neck fractures; in group B, 78/129 (60.5%) had femoral trochanteric fractures and 51% (39.5%) had femoral neck fractures; group A had a significantly higher proportion of

Table 1
Patient characteristics.

	Group A	Group B	P-value
N	117	129	
Age, yrs	79.51 ± 10.59	86.09 ± 7.41	< 0.001
Sex (male, female)	31, 86	33, 96	0.87
Weight, kg	51.82 ± 7.49	49.84 ± 6.58	0.22
BMI, kg/m^2	20.78 ± 3.28	21.19 ± 3.43	0.49
Fracture site			
–Femoral trochanteric fracture	36 (30.8%)	78 (60.5%)	< 0.0001
–Femoral neck fracture	81 (69.2%)	51 (39.5%)	
Preoperative walking ability			
–Outdoor walkable	88 (75.2%)	38 (29.5%)	
–Indoor walkable without aids	19 (16.2%)	58 (45.0%)	
–Requires a cane or walker	10 (0.09%)	33 (25.6%)	< 0.0001
Surgical method			
–Open Reduction and Internal Fixation	71 (60.7%)	96 (74.4%)	0.0284
–Bipolar hip arthroplasty	46 (39.3%)	33 (25.6%)	
Post-operative weight restriction			
–Full load permission	110 (94.0%)	117 (90.7%)	0.352
–Unloaded	7 (6.0%)	12 (9.3%)	
Length of hospital stay, days	19.56 ± 6.81	20.25 ± 6.50	0.24
Preoperative PNI	45.47 ± 6.35	41.98 ± 5.65	< 0.0001
PNI 1 day after surgery	35.21 ± 5.03	32.43 ± 4.30	< 0.0001
PNI 1 week after surgery	36.26 ± 5.88	31.97 ± 4.64	< 0.0001
PNI 2 weeks after surgery	38.96 ± 6.01	34.49 ± 4.93	< 0.0001
Preoperative PNI ≥ 40	83.8%	58.9%	< 0.0001
Preoperative PNI ≥ 45	56.4%	29.5%	< 0.0001
Preoperative PNI ≥ 50	20.5%	7.0%	0.02
Energy intake 1 week after surgery, kcal	1411.0 ± 371.1	1104.1 ± 434.4	< 0.0001
Energy intake 2 weeks after surgery, kcal	1440.7 ± 347.4	1199.4 ± 426.5	< 0.0001
Preoperative BNP level, pg/mL	81.79 ± 80.95	128.28 ± 181.24	0.0854
Preoperative HbA1c level (%)	5.98 ± 0.66	6.06 ± 1.12	0.285
Preoperative eGFR, mL/min/1.73m^2	66.47 ± 26.21	60.52 ± 22.47	0.042

BMI, body mass index; BNP, brain natriuretic peptide; eGFR, estimated glomerular filtration rate.

femoral neck fractures. The surgical methods were ORIF 71/117 (60.7%) and BHA 46/117 (39.3%) for group A and ORIF 96/129 (74.4%) and BHA 33/129 (25.6%) for group B; BHA was significantly more common in group A. The percentage of patients who were allowed full loading the day after surgery was 110/117 (94.0%) in group A and 117/129 (90.7%) in group B; there was no significant difference between the two groups. The mean length of hospital stay was 19.6 ± 6.8 days in group A and 20.3 ± 6.5 days in group B, with no significant difference between the two groups. PNI in group A/B was 45.47 ± 6.35/41.98 ± 5.65 ($P < 0.0001$) before surgery, 35.21 ± 5.03/32.43 ± 4.30 ($P < 0.0001$) 1 day after surgery, 36.26 ± 5.88/31.97 ± 4.64 ($P < 0.0001$) 1 week after surgery, and 38.96 ± 6.01/34.39 ± 4.93 ($P < 0.0001$) 2 weeks after surgery. Energy intake was 1411.0 ± 371.1 kcal/1104.1 ± 434.4 kcal ($P < 0.0001$) 1 week after surgery and 1440.7 ± 347.4 kcal/1199.4 ± 426.4 kcal ($P < 0.0001$) 2 weeks after surgery. At all time points, PNI and energy intake were significantly lower in group B than in group A (Table 1).

Among all patients, 13.4% had preoperative PNI ≥50 (group A 20.5%, group B 7.0%, odds ratio 3.42, P = 0.02), 42.3% had preoperative PNI ≥ 45 (group A 56.4%, group B 29.5%, odds ratio 3.08, $P < 0.0001$), and 70.7 % had preoperative PNI ≥ 40 (group A 83.8%, group B 58.9%, odds ratio 3.58, $P < 0.0001$) (Table 1).

Because age, fracture site, and preoperative subdivided gait ability may have a significant impact on postoperative gait function, we decided to match these conditions and again compare groups A and B. Caliper matching was performed to pair-match groups A and B with age, fracture site, and subdivided preoperative walking ability to form groups A′ and B’. There were 51 patients in group A′ (mean age 84.61 ± 6.67 years, 9 males and 42 females) and 51 patients in group B′ (mean age 84.65 ± 6.67 years, 14 males and 37 females). (Table 2). There were no significant differences between the two groups in age, gender, BMI, fracture site, preoperative subdivided walking ability, surgical method, postoperative unloading orders, and preoperative blood test data (BNP, HbA1c, eGFR). The mean length of hospital stay was 20.0 ± 7.4 days in group A′ and 19.1 ± 5.2 days in group B′, with no significant differences between the two groups. PNI in group A’/B′ were 43.38 ± 6.74/42.60 ±

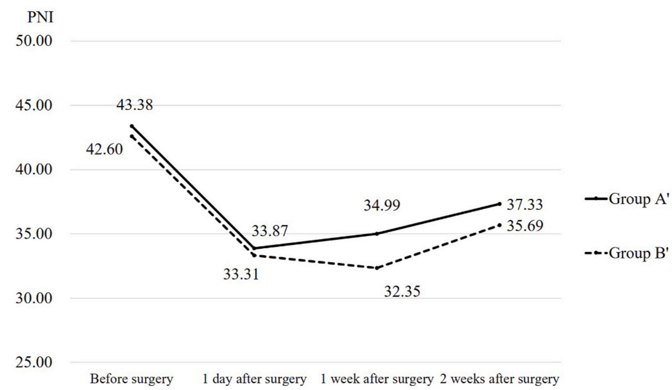

Fig. 1. Perioperative prognostic nutritional index (PNI) after age, preoperative subdivided walking ability, and fracture site matching.

Fig. 2. Postoperative energy intake after age, preoperative subdivided walking ability, and fracture site matching.

Table 2
Patient characteristics after age, fracture site, preoperative subdivided walking ability matching.

	Group A′	Group B′	P-value
N	51	51	
Age, yrs	84.61 ± 6.67	84.65 ± 6.67	0.93
Sex (male, female)	9, 42	14, 37	0.34
Weight, kg	48.90 ± 6.44	51.34 ± 6.79	0.03
BMI, kg/m^2	20.62 ± 3.51	20.99 ± 3.54	0.54
Fracture site			
–Femoral trochanteric fracture	20 (39.2%)	20 (39.2%)	1
–Femoral neck fracture	31 (60.8%)	31 (60.8%)	
Preoperative walking ability			
–Outdoor walkable	25 (49.0%)	25 (49.0%)	
–Indoor walkable without aids	16 (31.4%)	16 (31.4%)	1
–Requires a cane or walker	10 (19.6%)	10 (19.6%)	
Surgical method			
–Open Reduction and Internal Fixation	36 (70.6%)	28 (54.9%)	0.15
–Bipolar hip arthroplasty	15 (29.4%)	23 (45.1%)	
Post-operative weight restriction			
–Full load permission	48 (94.1%)	45(88.2%)	0.49
–Unloaded	3 (5.9%)	6 (11.8%)	
Length of hospital stay, days	20.00 ± 7.43	19.08 ± 5.20	0.75
Preoperative PNI	43.38 ± 6.74	42.60 ± 5.74	0.19
PNI 1 day after surgery	33.87 ± 4.87	33.31 ± 4.02	0.44
PNI 1 week after surgery	34.99 ± 5.86	32.35 ± 4.84	0.01
PNI 2 weeks after surgery	37.33 ± 6.26	35.69 ± 4.21	0.15
Energy intake 1 week after surgery, kcal	1380.8 ± 344.2	1203.1 ± 387.2	0.01
Energy intake 2 weeks after surgery, kcal	1382.0 ± 341.7	1225.6 ± 355.0	0.63
Preoperative BNP level, pg/mL	92.31 ± 85.64	119.18 ± 206.45	0.64
Preoperative HbA1c level (%)	5.84 ± 0.52	6.07 ± 1.02	0.77
Preoperative eGFR, mL/min/1.73m^2	71.47 ± 28.78	62.54 ± 23.40	0.17

BMI, body mass index; BNP, brain natriuretic peptide; eGFR, estimated glomerular filtration rate.

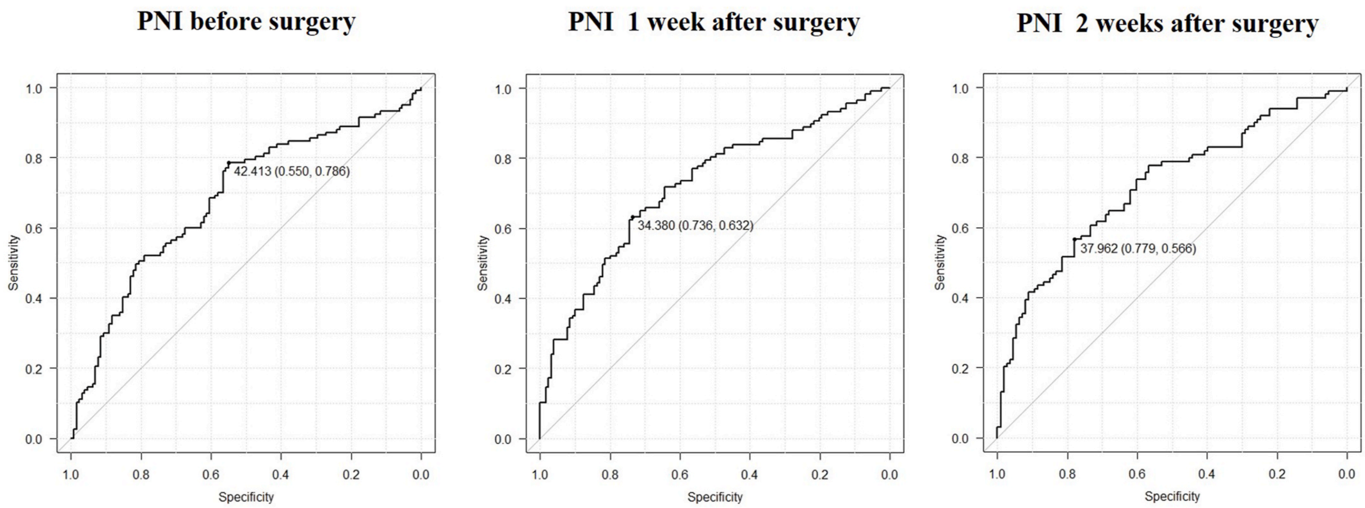

Fig. 3. Receiver operating characteristic (ROC) curves for patients able to walk at discharge. PNI, prognostic nutritional index.

5.74 (P = 0.19) before surgery, 33.87 ± 4.87/33.31 ± 4.02 (P = 0.44) 1 day after surgery, 34.99 ± 5.86/32.35 ± 4.84 (P = 0.01) 1 week after surgery, and 37.33 ± 6.26/35.69 ± 4.21 (P = 0.15) 2 weeks after surgery. When matched for age, fracture site, and preoperative subdivided walking ability, the PNI at 1 week postoperatively was significantly higher in group A′ than in group B’ (Fig. 1). Energy intakes in group A’/B′ were 1380.8 ± 344.2 kcal/1203.1 ± 387.2 kcal (P = 0.01) 1 week after surgery and 1382.0 ± 341.7 kcal/1225.6 ± 355.0 kcal (P = 0.63) 2 weeks after surgery. Energy intake at 1 week postoperatively was significantly higher in the A′ group than in the B′ group (Table 2, Fig. 2).

The optimal cut-off values for PNI in group A before and 1 and 2 weeks after surgery were 42.4 (sensitivity 0.55, specificity 0.79, area under the curve 0.68), 34.4 (sensitivity 0.74, specificity 0.63, area under the curve 0.72), and 38.0 (sensitivity 0.78, specificity 0.57, area under the curve 0.72), respectively (Fig. 3).

Depending on the postoperative food intake rate, the attending physician individually determined the need for nutrition and swallowing team intervention, and the nutrition and swallowing team intervened in 7.7% of group A patients and in 29.5% of group B patients, providing nutrition intervention including swallowing training and additional nutritional supplements.

4. Discussion

PNI was initially proposed as a method for evaluating surgical tolerance in gastrointestinal anastomosis surgery, with PNI < 40 indicating a surgical risk zone and contraindication to anastomosis [4]. It was subsequently shown to be useful as a predictor of perioperative complications in orthopedic surgery [5]. Preoperative PNI has been associated with perioperative complications, such as postoperative delirium, SSI, and postoperative death, in patients with fragile hip fractures [6–9]. Kurosu reported an increase in postoperative complications following cervical spine surgery in patients with PNI < 50 [16]. In the present study, the rate of preoperative PNI ≥ 50 was 13.4% (group A 20.5%, group B 7.0%, odds ratio 3.42, P = 0.02), that of preoperative PNI ≥ 45 was 42.3% (group A 56.4%, group B 29.5%, odds ratio 3.08, P < 0.0001), and that of preoperative PNI ≥ 40 was 70.7% (group A 83.8%, group B 58.9%, odds ratio 3.58, P < 0.0001), with a significantly higher preoperative PNI in group A than in group B. These results suggest that preoperative PNI is useful not only for predicting perioperative complications, but also for the early postoperative recovery of walking ability.

In this study, PNI at 1 week postoperatively and energy intake at 1 week postoperatively were significantly higher in the postoperatively ambulatory group than in the group that did not regain ambulation after surgery, even after adjusting for conditions such as age, fracture site, and preoperative subdivided walking ability. The incidence of nutritional disorders in patients with fragile hip fractures was previously reported to be 28%–60% [3,17]. In the present study, 57.7% of patients were malnourished with preoperative PNI < 45. Kaiser [10] demonstrated that only 14% of all hospitalized patients in acute care hospitals had an adequate energy intake. In functional training, aggressive exercise therapy under a low nutritional status or inappropriate nutritional management may lead to malnutrition, muscle weakness, and endurance loss due to increased protein catabolism caused by energy deficiency; therefore, nutritional therapy needs to be prioritized over exercise therapy in patients with a low nutritional status [11]. The perioperative energy intake of patients with hip fractures may be lower than required, but may be increased to close to the required level using nutritional supplements and the intervention of a nutritionist [18,19]. Intensive perioperative nutritional interventions for patients with hip fractures have also been shown to improve nutritional status indices, reduce postoperative complications, shorten hospital stays, maintain quality of life, and increase the rate of discharge [19–22].

One nutritional intervention for malnourished patients is the use of high-protein, high-calorie oral nutritional supplements (ONS) [23]. The intake of essential amino acids is required for muscle synthesis and effectively improves muscle strength [24]. The 2021 Korean clinical practice guidelines recommend high protein supplementation reaching 1.0–1.2 g/kg/day after hip surgery to maintain muscle mass and strength [25]. Ekinci showed that a perioperative nutritional intervention with ONS improved walking ability in patients with fragile hip fractures; among hip fracture patients who were able to walk after surgery, 81.3% in the nutrition intervention group were able to walk by postoperative day 15, in contrast to only 26.7% in the control group (P = 0.01) [26].

The perioperative nutritional status has been associated with mid- and long-term walking function, with preoperative malnutrition in hip fracture surgery being associated with a reduced walking ability 6 months after surgery and with the Harris Hip Score 3 months after surgery [12,13]. On the other hand, limited information is currently available on the perioperative nutritional status and walking ability in the early postoperative period [14,26]. In this study, short-term observations in an acute care hospital showed that PNI and energy intake at 1 week postoperatively were associated with early postoperative regain of walking ability. In addition, the results obtained revealed that PNI decreased 1 day after surgery and then gradually recovered 1 week after surgery in group A′, while it worsened until 1 week after surgery in group B′ and then started to recover 2 weeks after surgery (Fig. 1). The decrease observed in PNI 1 day after surgery in both groups may be attributed to fasting on the day of surgery and increased protein catabolism caused by surgical invasion. On the other hand, in contrast to group B′, PNI was higher in group A′ 1 week after surgery, suggesting that an improvement in the nutritional status in the early postoperative period was associated with the recovery of walking ability in the same period.

The optimal cut-off values for PNI in patients who were able to walk at discharge from the hospital were 42.4 before surgery, 34.4 1 week after surgery, and 38.0 2 weeks after surgery. Nutritional management aiming for PNI at least above these values may achieve the early postoperative recovery of walking ability (Fig. 3).

While few patients in acute care hospitals have an adequate nutritional intake, nutritional interventions not only improve nutritional indices, but also reduce postoperative complications and improve postoperative motor function [10,18–22,26]. The present study suggests that early postoperative PNI and early postoperative energy intake, especially up to 1 week postoperatively, are associated with the early postoperative recovery of walking ability. Therefore, the nutritional status needs to be monitored in the early postoperative period and an adequate energy intake needs to be promoted, including the consideration of nutritional interventions, such as ONS, to restore walking ability.

Okubo [27] reported that preoperative sarcopenia index, calculated as the ratio of serum creatinine to cystatin C levels, reflects skeletal muscle mass and strength and could predict postoperative walking ability at 2 weeks after surgery. Our present study showed that nutritional status in the very early postoperative period, up to 1 week postoperatively, may also affect the ability to walk at 2 weeks postoperatively.

Early postoperative mobilization is essential for patients undergoing hip fracture surgery to regain the pre-fracture functional level, not only in the short but also in the long term [28,29]. Münter [30] reported that fatigue, followed by hip fracture-related pain and the habitual cognitive status of patients with hip fracture are the most frequent reasons for not regaining basic mobility independence and not completing planned physiotherapy during the first 3 postoperative days, and at the hospital discharge (median day 10), only 54% of the patients had regained their pre-fracture basic mobility level. Bocanegra [31] also showed that the lower energy and protein intakes are associated with poorer mobilization at discharge (at the postoperative 6.9 ± 2.7 days) in hip fracture. As the results of our present study indicate, undernutrition in the very early postoperative period may be a cause of the inability to regain walking ability in the early postoperative period. One of the main targets after hip fracture surgery is the ability to walk independently to prevent patients from being institutionalized. Therefore, especially in the elderly, it may be important to improve nutritional status up to 1 week postoperatively through nutritional intervention starting immediately after surgery.

It is possible that post-operative walking ability affected postoperative energy intake and nutritional status, which is the limitation of the present study. To resolve this limitation, a prospective study is needed on the impact of early postoperative nutritional supplementation on the reacquisition of walking ability in the early postoperative period.

5. Conclusions

In the present study on hip fracture surgery in the elderly in an acute care hospital, PNI and energy intake at 1 week postoperatively were higher in patients who were able to walk at discharge than in those who were unable to walk at discharge. Postoperative PNI needs to be monitored closely and appropriate energy intake needs to be supported for the early postoperative recovery of walking ability.

Data availability statement

Data that support the results of the present study are available from the corresponding author upon reasonable request.

CRediT author statement

Kumiko Yotsuya: Conceptualization, Formal analysis, Investigation, Writing – original draft, Visualization. **Kaoru Yamazaki:** Conceptualization, Investigation, Writing – review & editing, Supervision. **Junichiro Sarukawa:** Writing – review & editing. **Tatsuya Yasuda:** Writing – review & editing. **Yukihiro Matsuyama:** Writing – review & editing.

Conflicts of interest

The authors declare no competing interests.

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