Journal of Anesthesia (2024) 38:57–64
https://doi.org/10.1007/s00540-023-03278-1

ORIGINAL ARTICLE

Perioperative loss of the psoas major muscle area index in elderly patients with hip fracture: spinal anesthesia versus general anesthesia—a retrospective cohort study

Yoshie Noji[1,2] · **Satoki Inoue**[2] · **Kazuhiro Watanabe**[1] · **Shinju Obara**[2]

Received: 19 June 2023 / Accepted: 17 October 2023 / Published online: 13 November 2023

Abstract

Purpose In hip fracture patients aged ≥ 80 years, we investigated whether the perioperative reduction in the psoas major muscle index (PMI) for spinal anesthesia was less than that for general anesthesia.

Methods A total of 262 patients surgically treated for intertrochanteric or femoral neck fractures between August 2015 and August 2022 were enrolled. After adjusting for propensity score matching, 50 patients were included in this analysis. After matching, patients were divided into those receiving spinal or general anesthesia.

We measured the psoas major muscle area (PMA) by adjusting for the patient's height as PMA (cm^2) divided by height (m) squared. The adjusted PMA was defined as the PMI. We calculated the variability in PMI (ΔPMI) before and after surgery. The primary outcome was the proportion of patients with a > 10% reduction in ΔPMI. The secondary outcomes were the mean ΔPMI and estimated factors affecting the postoperative reduction in the PMI. We compared the primary and secondary outcomes between spinal and general anesthesia.

Results The proportion with $a > 10\%$ reduction in ΔPMI did not differ between spinal and general anesthesia (36.0% vs. 40.0%, odds ratio:1.19, 95% CI:0.38–3.72, $p = 0.31$). The ΔPMI did not differ between spinal and general anesthesia ($-8.7\% \pm 7.9\%$ vs. $-8.9\% \pm 8.3\%$, $p = 0.93$). The factors affecting the postoperative reduction in the PMI were male sex, preoperative non-sarcopenia, and intramedullary nailing.

Conclusion There was no significant difference in ΔPMI between hip fracture patients ≥ 80 years of age receiving spinal versus general anesthesia undergoing surgical treatment.

Keywords Sarcopenia · Psoas major muscle area · Hip fracture

Introduction

Hip fractures in the elderly are common and increasingly frequent diseases. Inevitably, the number of patients with hip fractures that require surgery will increase. Many studies have been conducted concerning the prognosis of hip fracture, showing that age and preoperative mobility are associated with the prognosis [1, 2]. Mobility is associated with muscle strength and muscle mass [3, 4]. In some cases, the psoas major muscle index (PMI) is used to assess the appendicular skeletal muscle mass [5]. A low psoas major muscle area (PMA) with initial intertrochanteric fracture has been reported as a risk factor for contralateral hip fracture [6]. To prevent contralateral hip fracture, it is important to preserve PMA in the perioperative period in patients with hip fracture, and significant muscle weakness and physical disability can sometimes persist for more than five years after surgery. Sarcopenia, in which the loss of muscle mass is considered to be a diagnostic criterion, is also associated with frailty. In Japan, where the population is rapidly aging, approximately 35% of patients ≥ 80 years old are reported to be frail [7], thus making it particularly important to maintain muscle mass in the elderly.

There have also been many reports on anesthesia methods for hip fracture surgery [8–10]. Recently, the

✉ Yoshie Noji
noyoshie@fmu.ac.jp

[1] Department of Anesthesiology, Aidu Chuo Hospital, 1-1, Tsuruga-Machi, Aizuwakamatsu, Fukushima 965-8611, Japan

[2] Department of Anesthesiology, Fukushima Medical University, Fukushima, Japan

REGAIN [11] and RAGA [12] trials showed that spinal anesthesia was not associated with better early postoperative outcomes than general anesthesia. These trials were designed to test the hypothesis that spinal anesthesia is superior to general anesthesia. However, the results showed no marked differences between patients receiving spinal and general anesthesia. Many factors affect the perioperative loss of muscle mass. We focused on the muscle mass before and after surgery in elderly patients with hip fractures. The effect of anesthesia methods on PMA in elderly patients with hip fractures remains unknown. If the anesthetic method does indeed affect postoperative PMA, then this would be an interesting clinical question to explore. A previous study showed an anticatabolic effect of neuraxial blockade rather than general anesthesia after hip surgery [13]. Therefore, we hypothesized that spinal anesthesia would be superior to general anesthesia in preserving the perioperative PMA in patients with hip fractures.

Therefore, we investigated whether the reduction in PMA during the perioperative period for spinal anesthesia was less than that for general anesthesia in patients with hip fracture aged ≥ 80 years.

Methods and materials

Study design and patient selection

This was a single-center, retrospective cohort study. The institutional review board of Aidu Chuo Hospital approved the study protocol and opt-out consent (approval number:2202; date of approval:2022.10.29).

The inclusion criteria were as follows: (1) patients diagnosed with hip fracture, defined as a femoral neck fracture or femoral intertrochanteric fracture, surgically treated between August 2015 and August 2022, and who underwent one of the following procedures: bipolar hemiarthroplasty or intramedullary nailing for hip fracture; (2) low-energy trauma; (3) men and women ≥ 80 years old; and (4) pelvic computed tomography (CT) performed before and after surgery. We defined low-energy trauma as a fall from a standing position or a height of < 1 m [14]. The exclusion criteria were as follows: (1) patients with a repeat hip fracture, such as those with a history of contralateral hip fracture or postoperative refracture; (2) patients with metastatic pathological fracture; (3) patients who underwent surgery for reasons other than hip fracture simultaneously; (4) patients with insufficient data, for example, CT did not show the psoas major muscle; and (5) patients judged to be nonconforming for other reasons.

Anesthesia method

The anesthesia method initially selected at our institution during this study period was spinal anesthesia. General anesthesia was selected over spinal anesthesia in the following cases: (1) patients with coagulopathy; (2) patients with inadequate withdrawal period from preoperative antithrombotic therapy; (3) patients with infection at the site of injection; and (4) other reasons, such as at the patient's request or anesthesiologist's preference. For patients undergoing spinal anesthesia, we administered single-injection spinal anesthesia at L2/3 or L3/4 in the right or left lateral position. We administered 15 mg (3.0 mL) of 0.5% isobaric bupivacaine to each patient under spinal anesthesia. None of the patients in this study was sedated. For patients undergoing general anesthesia, we used an inhaled anesthetic agent (sevoflurane or desflurane) for maintenance and an endotracheal tube or supraglottic airway for airway management. We administered rocuronium according to clinical needs, as assessed by the Train of Four (Intelivue NMT module; Philips, Amsterdam, the Netherlands), and sugammadex for residual neuromuscular blockade. For both anesthesia methods, we performed peripheral nerve blocks as a combination of femoral nerve block and lateral femoral cutaneous nerve block or fascia iliac compartment block with ropivacaine, as needed.

Data collection and analyses

Pelvic CT was performed using an Aquilion ONE (Canon Medical Systems Corporation, Tochigi, Japan) or SOMATOM (Siemens, Munich, Germany) with 1.0-, 3.0-, or 5.0-mm-thick slices to evaluate the fracture pattern and decide on a surgical plan in patients with hip fractures–0–13 day before the surgical procedure. Similarly, postoperative CT was performed to check for postoperative detailed dislocations on postoperative day 1–17. These preoperative and postoperative images were transferred to a workstation (EV Insite; PSP, Tokyo, Japan), where they were displayed side-by-side, and we selected images at the level of the lower fourth lumbar vertebra. We identified the bilateral psoas major muscles at this level and manually selected the area (Fig. 1). The cross-sectional area (cm^2) was automatically calculated using EV Insite and defined as the PMA. After calculating the PMA, we adjusted it for the patient's height as the PMA (cm^2) divided by the height (m) squared, which is commonly used to adjust the cross-sectional area of the psoas major muscle [5, 15]. We defined this adjusted cross-sectional area as PMI (cm^2/m^2).

We compared the preoperative and postoperative PMI values and defined ΔPMI as the difference between the preoperative and postoperative PMI by calculating ΔPMI

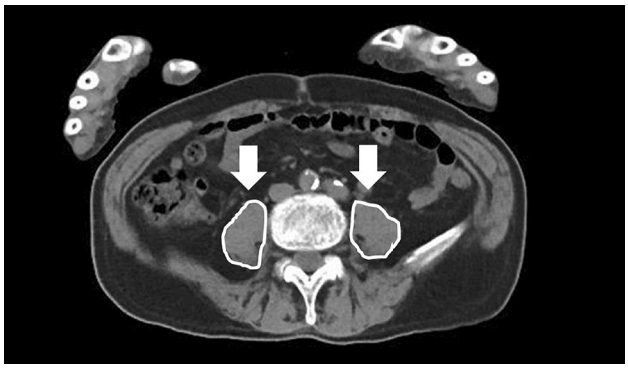

Fig. 1 The measurement of psoas major muscle area (PMA). PMA (white arrow) at the fourth lumber vertebra level was measured by CT

(%) as 100 × (postoperative PMI/preoperative PMI). We also recorded the number of days between preoperative and postoperative CT scans.

Propensity score matching

As this was a retrospective study, there were some selection biases or confounding factors. Propensity score matching was performed to eliminate biases and confounding factors. We selected the following factors as prognostic or muscle mass-related factors in previous studies: the age, sex, American Society of Anesthesiologists physical status (ASA-PS), body mass index (BMI), preoperative sarcopenia defined by preoperative PMI (cutoff values: men 6.36 cm^2/m^2, women 3.92 cm^2/m^2 [5]), surgery type (bipolar hemiarthroplasty or intramedullary nailing), ischemic heart disease (IHD), valvular heart disease (moderate or severe), cerebrovascular disease, chronic kidney disease (defined as creatinine > 2.0 mg/dL or dialysis in this study), history of cancer, preinjury dementia, chronic obstructive pulmonary disease (COPD), diabetes mellitus (DM), and the number of days between pre- and post-operative CT (days between CT) [11, 12, 16]. The calculation of the propensity score was determined as a caliper width of 0.2 times the standard deviation of the propensity score in all patients. A matching ratio of 1:1 was used for this study.

Outcomes measures

The Global Leadership Initiative on Malnutrition (GLIM) criteria [17], as indicators of nutritional status associated with sarcopenia, do not show a clear cut-off for the loss of muscle mass. However, the GLIM criteria also show weight loss > 10% beyond 6 months as a phenotypic and etiologic criterion for the diagnosis of malnutrition. A previous report found that a loss of skeletal muscle mass of ≥ 10% in the perioperative period was a prognostic factor for overall survival [18]. A report examining the variability in perioperative muscle mass in patients who received general anesthesia showed a 9.16% loss in muscle mass [19] following major abdominal surgery in older adults. Given these findings, we considered a muscle mass loss > 10% as the clinical cutoff value for the reduction of PMI.

The primary outcome was the proportion of patients who showed a > 10% reduction in ΔPMI in each group. The secondary outcome was the calculation of the mean ΔPMI for each group and estimating factors affecting the postoperative reduction of PMI, including anesthesia type. Patient outcomes were compared between the spinal anesthesia and general anesthesia groups using the total population and then between the spinal anesthesia and general anesthesia groups after propensity score matching. To estimate the factors affecting the postoperative reduction in the PMI, we used the total population.

Sample size calculation

A previous report showed variability in perioperative muscle mass in patients who received general anesthesia, with a mean 9.16% reduction [19]. Based on these findings, we assumed that 50% of the patients in the group receiving general anesthesia with neuromuscular blockade would have a > 10% reduction in ΔPMI. To our knowledge, there have been no definitive reports on the relationship between spinal anesthesia and muscle mass loss. Patients resting in bed have been reported to show a reduction in muscle mass of approximately 0.5% to 1% per day [20, 21]. Assuming that the number of days between the pre- and post-operative CT assessment is 6 days, a muscle mass loss of approximately 3–6% is considered. However, there were some patients with a > 10% reduction in ΔPMI. We suspected that approximately 10% of the patients in the group receiving spinal anesthesia, without the intervention of general anesthesia, would show a > 10% reduction in ΔPMI. Based on these assumptions, we calculated the sample size for McNemar's test with an α error of 0.05, a power of 0.8, and a two-sided test, which resulted in 25 cases required in each group.

Statistical analyses

We determined that the patients' characteristics were balanced, with a standardized mean difference of < 10%. We considered a > 10% reduction in ΔPMI as categorical data and compared the proportions with a > 10% reduction in ΔPMI between patients receiving spinal and general anesthesia in the total population before and after matching using Fisher's exact test or McNemar's test. In the total population, before and after matching, we also compared the mean ΔPMI ± standard deviation using a *t* test between patients receiving spinal and general anesthesia. We also calculated

the effect size of Cohen's d before and after matching between patients receiving spinal and general anesthesia. All statistical analyses were performed using a two-sided significance level of 0.05.

In addition, we performed an additional logistic regression analysis in the total population before matching to confirm whether the anesthesia method was significantly associated with a > 10% reduction in the ΔPMI. Candidate variables with a significant univariate association ($p < 0.15$) and a > 10% reduction in ΔPMI were used to perform logistic regression analysis using forced-entry methods. We considered factors with $p < 0.05$ as independent predictors.

All statistical analyses were performed using EZR Version 1.55 (Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R Version 2.7–1 (The R Foundation for Statistical Computing, Vienna, Austria) [22].

Results

The study flowchart for enrollment is shown in Fig. 2. Propensity score matching resulted in 25 matched pairs of patients in the spinal anesthesia group (group S) and the general anesthesia group (group G), where 2 and 12 patients received peripheral nerve blocks, respectively.

Patient characteristics of the two unmatched groups are shown in Table 1. Only BMI, surgery type, and days between CT were balanced before matching. In spinal anesthesia, 72 patients (31.6%) had a > 10% reduction in ΔPMI, whereas in general anesthesia, 11 patients (32.4%) had a > 10% reduction in ΔPMI. Patient outcomes before matching are summarized in Table 2. The proportion of patients with a > 10% reduction in the ΔPMI was not significantly different between spinal anesthesia and general anesthesia (31.6% vs. 32.4%, odds ratio 1.04, 95% CI:0.48–2.24, $p = 1.00$). In spinal anesthesia, the mean ΔPMI was − 7.9% ± 6.6%, while in general anesthesia, the mean ΔPMI was − 7.8% ± 7.7%. There was no significant difference between the groups ($p = 0.90$). The effect size (Cohen's d) is 0.01.

The patient characteristics of the two groups after matching are shown in Table 3. Even after matching, five characteristics, surgery type, cerebrovascular disease, chronic kidney disease defined as creatinine > 2.0 mg/dL or dialysis, diabetes mellitus and days between CT remained unbalanced. Patient outcomes after matching are summarized in Table 4. In group S, 9 patients (36.0%) had a > 10% reduction in ΔPMI, and in group G, 10 patients (40.0%) had a > 10% reduction in ΔPMI. The proportion with a > 10% reduction in the ΔPMI did not significantly differ between groups S and G (36.0% vs. 40.0%, odds ratio:1.19, 95% CI:0.38–3.72, $p = 0.31$). In group S, the mean ΔPMI was − 8.7% ± 7.9%, and in group G, the mean ΔPMI was − 8.9% ± 8.3%. There was no significant difference between groups S and G ($p = 0.93$). The effect size (Cohen's d) is 0.03.

A logistic regression analysis showed that male sex, preoperative non-sarcopenia defined by the PMI, and intramedullary nailing were independent risk factors associated with a > 10% reduction in the ΔPMI (Table 5). However, the anesthesia method did not result in a > 10% reduction in ΔPMI, even after adjusting for the explanatory variables. The final model discrimination assessed using the likelihood ratio test was significant ($p < 0.0001$).

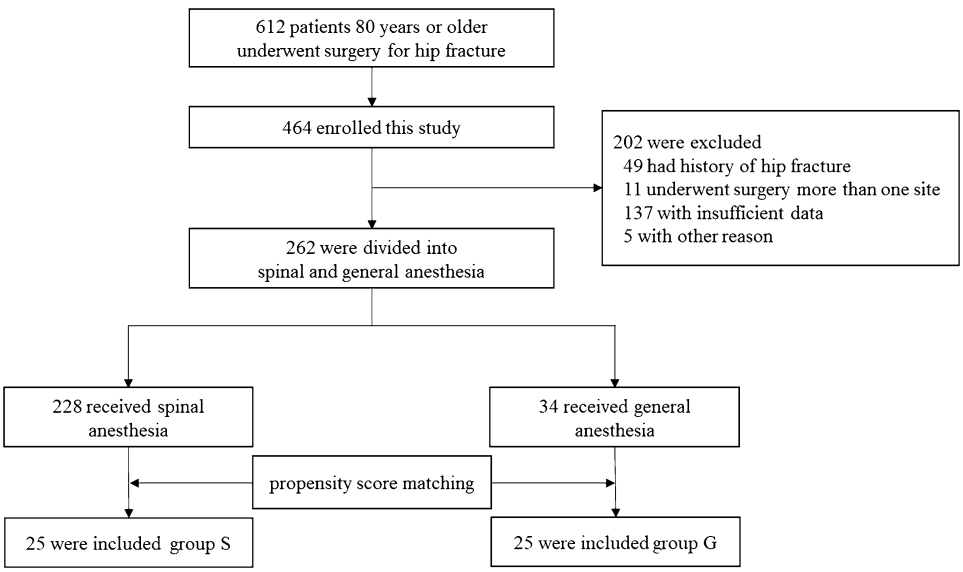

Fig. 2 Study flow chart

Table 1 Patient characteristics in the two groups before matching

Variables	Spinal ($n=228$)	General ($n=34$)	p value	SMD
Mean age, years (*SD*)	89.2 (4.8)	86.5 (3.4)	0.001	0.66
ASA-PS, median (*IQR*)	3 (2–3)	3 (2–3)	0.001	0.64
Male, *n* (%)	56 (24.6)	10 (29.4)	0.53	0.11
Mean BMI (*SD*)	21.1 (3.6)	21.3 (3.2)	0.82	0.05
Preoperative sarcopenia, *n* (%)	40 (17.5)	18 (52.9)	< 0.001	0.80
Bipolar hemiarthroplasty, *n* (%)	79 (34.6)	13 (31.2)	0.70	0.08
Ischemic heart disease, *n* (%)	19 (8.3)	9 (26.5)	0.004	0.49
Valvular disease, *n* (%)	59 (25.9)	7 (20.6)	0.67	0.13
Cerebrovascular disease, *n* (%)	31 (13.6)	15 (44.1)	< 0.001	0.72
Chronic obstructive pulmonary disease, *n* (%)	3 (1.3)	0 (0)	1.00	0.16
Creatinine > 2.0 mg/dL or dialysis, *n* (%)	7 (3.1)	2 (5.9)	0.33	0.14
History of cancer, *n* (%)	46 (20.2)	9 (26.5)	0.38	0.15
Dementia, *n* (%)	89 (39.0)	10 (29.4)	0.35	0.20
Diabetes mellitus, *n* (%)	32 (14.0)	9 (26.5)	0.08	0.31
Days between CT, median (*IQR*)	5 (4–7)	5.5 (4–7)	0.81	0.02

SMD standardized mean difference, *SD* standard deviation, *ASA-PS* American society of anesthesiologists physical status, *BMI* body mass index, *CT* computed tomography, *IQR* interquartile range

Table 2 Patient outcomes before matching

	Spinal ($n=228$)	General ($n=34$)	Odds ratio	95% CI	Cohen's d	p value
> 10% reduction in the ΔPMI, *n* (%)	72 (31.6)	11 (32.4)	1.04	0.48–2.24		1.00
ΔPMI (*SD*)	− 7.9 (6.6)	− 7.8 (7.7)			0.01	0.90

CI confidence interval, *PMI* psoas major muscle index, *SD* standard deviation

Table 3 Patient characteristics of the two groups after propensity score matching

Variables	Group S ($n=25$)	Group G ($n=25$)	p value	SMD
Mean age, years (*SD*)	86.5 (4.2)	86.8 (3.5)	0.80	0.07
ASA-PS, median (*IQR*)	3 (2–3)	3 (2–3)	1.00	0.08
Male, *n* (%)	7 (28.0)	7 (28.0)	1.00	< 0.001
Mean BMI (*SD*)	21.6 (3.9)	21.5 (3.1)	0.95	0.02
Preoperative sarcopenia, *n* (%)	10 (40.0)	10 (40.0)	1.00	< 0.001
Bipolar hemiarthoplasty, *n* (%)	7 (28.0)	10 (40.0)	0.55	0.26
Ischemic heart disease, *n* (%)	6 (24.0)	7 (28.0)	1.00	0.09
Valvular disease, *n* (%)	6 (24.0)	5 (20.0)	1.00	0.097
Cerebrovascular disease, *n* (%)	12 (48.0)	10 (40.0)	0.78	0.16
Chronic obstructive pulmonary disease, *n* (%)	0 (0)	0 (0)		< 0.001
Creatinine > 2.0 mg/dL or dialysis, *n* (%)	0 (0)	1 (4.0)	1.00	0.29
History of cancer, *n* (%)	5 (20.0)	6 (24.0)	1.00	0.097
Dementia, *n* (%)	6 (24.0)	7 (28.0)	1.00	0.09
Diabetes mellitus, *n* (%)	7 (28.0)	5 (20.0)	0.74	0.19
Days between CT, median (*IQR*)	6 (5–8)	5 (4–7)	0.38	0.25

SMD standardized mean difference, *SD* standard deviation, *ASA-PS* American society of anesthesiologists physical status, *BMI* body mass index, *CT* computed tomography, *IQR* interquartile range

Table 4 Patient outcomes after propensity score matching

	Group S ($n=25$)	Group G ($n=25$)	Odds ratio	95% CI	Cohen's d	p value
> 10% reduction in the ΔPMI, n (%)	9 (36.0)	10 (40.0)	1.19	0.38–3.72		0.31
ΔPMI (*SD*)	− 8.7 (7.9)	− 8.9 (8.3)			0.03	0.93

CI confidence interval, *PMI* psoas major muscle index, *SD* standard deviation

Table 5 Results of a logistic regression analysis for > 10% reduction in the ΔPMI

Explanatory variables	Odds ratio	95% CI	p value
anesthesia method (general)	1.42	0.58–3.46	0.44
age (years)	0.97	0.91–1.03	0.30
sex (female)	0.43	0.20–0.92	0.03
BMI	1.02	0.94–1.10	0.65
preoperative sarcopenia defined by PMI	0.36	0.15–0.86	0.02
surgery type (intramedullary nailing)	5.13	2.55–10.30	< 0.001

PMI psoas major muscle index, *CI* confidence interval, *BMI* body mass index

Discussion

The present study revealed no significant differences in the ΔPMI between spinal anesthesia and general anesthesia in patients with hip fractures undergoing therapeutic surgery.

Recent studies have found no significant difference in early postoperative outcomes based on anesthesia methods, comparing spinal and general anesthesia for surgical correction of hip fractures [11, 12, 23]. Our findings support those of previous reports on the preservation of PMI. A preoperative PMI reduction in patients with hip fractures has been reported to be a risk factor for contralateral hip fracture [6]. To prevent contralateral hip fracture and maintain the patient's activities of daily living (ADL), perioperative management does not lead to a loss of muscle mass, quality and function.

The present study showed that male sex, preoperative non-sarcopenia, and intramedullary nailing were independent risk factors for a > 10% reduction in the ΔPMI. This was thought to be because males had more original muscle mass than females, leaving more room for loss of muscle mass in males than in females. The same was assumed for preoperative non-sarcopenia and sarcopenia. In most cases, intramedullary nailing was performed for femoral intertrochanteric fractures, and bipolar hemiarthroplasty was performed for femoral neck fractures. Patients with neck fractures underwent preoperative interventions for mobilization, while patients with intertrochanteric fractures were often placed on stricter bed rest to prevent dislocation. This difference in preoperative management was thought to have affected the muscle mass.

The psoas major muscle is important for maintaining posture and controlling hip movement. The PMI is a tool used to evaluate muscle mass in sarcopenia [5, 15]. The skeletal muscle mass index (SMI) and PMI were measured using CT or magnetic resonance imaging. Compared to the SMI, the PMI, which is calculated by measuring only the psoas major muscle area, is considered more convenient. Previous studies have reported PMI in diseases other than hip fractures. In major colorectal surgery, sarcopenia, defined by the PMI, was reported to be an independent predictor of two-year mortality, major complications, and severity of complications [15]. Another study reported that in liver transplantation, low PMI was an independent prognostic factor for poor post-transplant survival [24]. The PMI has also been reported as part of the Sarcopenia Aneurysm Scoring System for predicting early and mid-term mortality in endovascular repair of abdominal aortic aneurysms [25]. As these studies have shown, a low PMI is a predictor of postoperative complications and poor prognosis in some procedures. However, to our knowledge, no studies have examined the association between anesthesia and PMI. Therefore, whether the modality of anesthesia affects perioperative PMI should be clarified, as it might necessitate the radical reform of our anesthesia practice.

Despite propensity score matching, five characteristics, surgery type, cerebrovascular disease, chronic kidney disease defined as creatinine > 2.0 mg/dL or dialysis, diabetes mellitus and days between CT, were imbalanced. In this study, the caliper width was 0.2 times the standard deviation of the propensity score. Consequently, 25 patients in each group were matched in this study. Although the overall scores were similar in the matched patients, they were originally highly skewed in each group, and it was believed that the scores for each characteristic alone were imbalanced.

We hypothesized that 10% of the patients in group S and 50% of the patients in group G would have a > 10% reduction

in ΔPMI when calculating the sample size. However, a > 10% reduction in ΔPMI was observed in approximately 30–40% of patients in both groups. In group S, additional surgical invasion and bed rest may have increased muscle protein catabolism, resulting in muscle loss in a larger number of patients than expected. In group G, the hypothesis was made with reference to open abdominal surgery under general anesthesia [19]. However, the number of patients was lower than expected because surgery for hip fracture is less invasive than open abdominal surgery, and there is less catabolism of muscle protein.

Based on the results of this study, we hypothesized that the proportion with a > 10% reduction in ΔPMI would be 30% in Group S and 35% in Group G. We needed a sample size of 1417 patients in each group to calculate the difference in the proportion with a > 10% reduction in the ΔPMI between groups S and G, with an α error of 0.05, a power of 0.8, and a two-sided test. This was considered to be too large and impractical. In addition, the results of the logistic regression analysis for the total population also indicated that the method of anesthesia did not affect the clinically significant reduction in the ΔPMI. It is believed that spinal anesthesia for hip fracture surgery is superior to general anesthesia. The current study addressed the clinical and practical importance and meaning of the results that the anesthesia method was not related to the ΔPMI, as a surrogate of postoperative muscle weakness.

Several limitations of the present study warrant mention. First, as described above, propensity score matching could not completely eliminate bias. Propensity score matching is also considered to have limitations, owing to the inherent bias of the groups being compared resulting from the choice of anesthesia method. Additionally, regarding the anesthesia methods, the effect of peripheral nerve blocks with each anesthesia method is not clear. Second, because this study was retrospective, the protocols applied, such as the anesthesia method and CT settings, were not uniform. Even in a prospective study, such as the REAGAIN trial [11], the protocol for general anesthesia varied slightly among facilities, it may be difficult to establish a strict protocol. Preoperative complications, such as pneumonia and acute kidney injury, increased the number of days between preoperative CT and surgery in some cases. There were also variations in the number of days between surgery and postoperative CT, which may have affected the muscle mass depending on the progress of rehabilitation. Third, we did not consider preoperative ADL; because this study compared the muscle mass of elderly patients, we deemed it better to consider preoperative walking ability, muscle strength, and muscle quality. In addition, we did not consider the effects of injury, procedure, or perioperative fluid management. Although the original trend in ΔPMI during the perioperative period was unclear, we observed a rough trend in ΔPMI in this study. Finally, we only examined perioperative ΔPMI. The relationship between ΔPMI, perioperative prognosis, and complications in patients with hip fractures is often unclear. The perioperative impact of PMI remains largely unknown. We hope that our findings will lead to further studies on anesthesia and PMI.

Conclusion

In conclusion, there was no significant difference in ΔPMI between hip fracture patients receiving spinal anesthesia and those receiving general anesthesia while undergoing surgical treatment. We failed to show that spinal anesthesia was superior to general anesthesia in terms of preserving the PMI in patients aged ≥ 80 years with hip fracture.

Author contributions YN designed the study, acquired the data, and prepared the manuscript. SI assisted in the preparation of the manuscript and statistical analysis. KW acquired the data. SO assisted in the conception and design of the study. All authors have read and approved the final manuscript.

Funding This research did not receive any specific grant from any public, commercial, or nonprofit funding agency.

Data availability The data that support the fndings of this study are available on request from the corresponding author, YN.

Declarations

Conflict of interest The authors declare no conflicts of interest.

References

1. Chirodian N, Arch B, Parker MJ. Sliding hip screw fixation of trochanteric hip fractures: outcome of 1024 procedures. Injury. 2005;36:793.
2. Larson S, Friberg S, Hanssonl LI. Trochanteric fractures. Mobility, complications, and mortality in 607 cases treated with the sliding-screw technique. Clin Orthop Relat Res. 1990;260:232–41.
3. Chen LK, Woo J, Assantachai P, Auyeung TW, Chou MY, Iijima K, Jang HC, Kang L, Kim M, Kim S, Kojima T, Kuzuya M, Lee JSW, Lee SY, Lee WJ, Lee Y, Liang CK, Lim JY, Lim WS, Peng LN, Sugimoto K, Tanaka T, Won CW, Yamada M, Zhang T, Akishita M, Arai H. Asian working group for sarcopnia 2019 consensus update on sarcopenia diagnosis and treatment. J Am Med Dir Assoc. 2020;21:300-307.e2.
4. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, Cooper C, Landi F, Rolland Y, Sayer AA, Schneider SM, Sieber CC, Topinkova E, Vandewoude M, Visser M, Zamboni M. Writing group for the European working group on sarcopenia in older people 2 (EWGSOP2), and the extended group for EWGSOP2: sarcopenia: revised European consensus on definition and diagnosis. Age Aging. 2019;48:16–31.
5. Hamaguchi Y, Kaido T, Okumura S, Kobayashi A, Hammad A, Tamai Y, Inagaki N, Uemoto S. Proposal for new diagnostic

criteria for low skeletal muscle, as based on computed tomography imaging in Asian adults. Nutrition. 2016;32:1200–5.
6. Kawakami T, Imagama T, Murakami T, Kaneoka T, Yamamoto M. Low psoas major muscle area as a risk factor for contralateral hip fracture following intertrochanteric fracture. J Musculoskelet Netronal Interact. 2021;21:495–500.
7. Kojima G, Iliffe S, Taniguchi Y, Shimada H, Rakugi H, Walters K. Prevalence of frailty in Japan: a systematic review and meta-analysis. J Epidemiol. 2017;27:347–53.
8. Brox WT, Chan PH, Cafri G, Inacio MCS. Similar mortality with general or regional anesthesia in elderly hip fracture patients. Acta Orthop. 2016;87:152–7.
9. Waesberghe JV, Stevanovic A, Rossaint R, Coburn M. General vs. neuraxial anaesthesia in hip fracture patients: a systematic review and meta-analysis. BMC Anesthesiol. 2017;17:87.
10. White SM, Moppett IK, Griffiths R. Outcome by mode of anaesthesia for hip fracture surgery. An observational audit of 65 535 patients in a national dataset. Anaesthesia. 2014;69:224–30.
11. Neuman MD, Feng R, Carson JL, Gaskins LJ, Dillane D, Sessler DI, Sieber F, Magaziner J, Marcantonio ER, Mehta S, Menio D, Ayad S, Stone T, Papp S, Schwenk ES, Elkassabany N, Marshall M, Jaffe JD, Luke C, Sharma B, Azim S, Hymes RA, Chin RJ, Sheppard R, Perlman B, Sappenfield J, Hauck E, Hoeft MA, Giska M, Ranganath Y, Tedore T, Choi S, Li J, Kwofie MK, Nader A, Sanders RD, Allen BFS, Vlassakov K, Kates S, Fleisher LA, Dattilo J, Tierney A, Stephens-Shields AJ, Ellenberg SS, REGAIN Investigators. Spinal anesthesia or general anesthesia for hip surgery in older adults. N Engl J Med. 2021;385:2025–35.
12. Li T, Li J, Yuan L, Wu J, Jian C, Daniels J, Mehta RL, Wang M, Yeung J, Jackson T, Melody T, Jin S, Yao Y, Wu J, Chen J, Smith FG, Lian Q, RAGA Study Investigators. Effect of regional vs general anesthesia on incidence of postoperative delirium in older patients undergoing hip fracture surgery: the RAGA randomized trial. JAMA. 2022;327:50–8.
13. Lattermann R, Belohlavek G, Wittmann S, Füchtmeier B, Gruber M. The anticatabolic effect of neuraxial blockade after hip surgery. Anesth Analg. 2005;101:1202–8.
14. Salminen S, Pihlajamäki H, Avikainen V, Kyrö A, Böstman O. Specific features associated with femoral shaft fractures caused by low-energy trauma. J Trauma. 1997;43:117–22.
15. Batista AFR, Petty D, Fairhurst C, Davies S. Psoas muscle mass index as a predictor of long-term mortality and severity of complications after major intra-abdominal colorectal surgery—a retrospective analysis. J Clin Anesth. 2023;84: 110995.
16. Dionyssiotis Y, Athanassiou P, Papathanasiou J, Efstathopoulos E, Prokopidis K, Trovas G, Kostoglou-Athanassiou I. Sarcopenia in patients with diabetes mellitus. Folia Med (Plovdiv). 2022;64:596–601.
17. Jensen GL, Cederholm T, Correia MITD, Gonzalez MC, Fukushima R, Higashiguchi T, Baptista GA, Barazzoni R, Blaauw R, Coats AJS, Crivelli A, Evans DC, Gramlich L, Fuchs-Tarlovsky V, Keller H, Llido L, Malone A, Mogensen KM, Morley JE, Muscaritoli M, Nyulasi I, Pirlich M, Pisprasert V, Schueren M, Siltharm S, Singer P, Tappenden KA, Velasco N, Waitzberg DL, Yamwong P, Yu J, Compher C, Gossum AV. GLIM criteria for the diagnosis of malnutrition e A consensus report from the global clinical nutrition community. JPEN J Parenter Enteral Nutr. 2019;43:32–40.
18. Itoh S, Yoshizumi T, Tomiyama T, Iseda N, Morinaga A, Shimagaki T, Wang H, Kurihara T, Nagao Y, Toshima T, Harada N, Nishie A, Ishigami K, Mori M. Impact and risk factors for skeletal muscle mass loss after hepatic resection in patients with hepatocellular carcinoma. JGH Open. 2021;5:785–92.
19. Hardy EJ, Hatt J, Doleman B, Smart TF, Piasecki M, Lund JN, Phillips BE. Post-operative electrical muscle stimulation attenuates loss of muscle mass and function following major abdominal surgery in older adults: a split body randomised control trial. Age Ageing. 2022;51:afac234.
20. Wall BT, Loon LJC. Nutritional strategies to attenuate muscle disuse atrophy. Nutr Rev. 2013;71:195–208.
21. Wall BT, Dirks ML, Loon LJC. Skeletal muscle atrophy during short-term disuse: implications for age-related sarcopenia. Ageing Res Rev. 2013;12:898–906.
22. Kanda Y. Investigation of the freely available easy-to-use software 'EZR' for medical statistics. Bone Marrow Transplant. 2013;48:452–8.
23. Griffiths R, Babu S, Dixon P, Freeman N, Hurford D, Kelleher E, Moppett I, Ray D, Sahota O, Shields M, White M. Guidelines for the management of hip fractures 2020. Anaesthesia. 2021;76:225–37.
24. Hamaguchi Y, Kaido T, Okumura S, Fujimoto Y, Ogawa K, Mori A, Hammad A, Tamai Y, Inagaki N, Uemoto S. Impact of quality as well as quantity of skeletal muscle on outcomes after liver transplantation. Liver Transpl. 2014;20:1413–9.
25. Ito E, Ohki T, Toya N, Fukushima S, Murakami Y, Nakagawa H, Nishie R, Misawa T. Sarcopenia aneurysm scoring system predicts early and midterm mortality after endvascular repair for abdominal aortic aneurysm. Ann Surg. 2022;276:e247–54.