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ORIGINAL RESEARCH

Comparison Between the Clinical Effect of Percutaneous Kyphoplasty for Osteoporosis Vertebral Compression Fracture Patient with or Without Sarcopenia: A Retrospective Cohort Study

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Background: Sarcopenia and osteoporosis vertebral compression fractures (OVCF) are common diseases that increase with age. This study aimed to investigate the effects of sarcopenia on OVCF patients after percutaneous kyphoplasty (PKP).

Methods: Data of 101 patients who were treated with single-level PKP between January 2021 and March 2022 at Ningbo No.6 Hospital were enrolled. Forty-five OVCF patients with sarcopenia who met our inclusion criteria were included in the Sarcopenia-PKP group (SPKP group), and 56 patients in the Normal-PKP group (NPKP group). All clinical and radiological data were collected from medical records. Baseline characteristics, operation-related parameters (operation time, time to ambulation, hospital stay, surgery segment), clinical outcomes (visual analog score [VAS], Oswestry Disability Index [ODI], Japanese Orthopaedic Association Scores [JOA] of lumber), radiological outcomes (vertebral anterior height rate and local kyphosis angle), Macnab score, and complications were evaluated and compared.

Results: There were no significant differences in age, sex, surgical segment preoperative VAS score, ODI, or JOA between the two groups ($P > 0.05$). The SPKP group had a significantly lower body mass index (BMI), bone mineral density (BMD), and smooth muscle index (SMI) than the NPKP group ($P < 0.05$). Significantly longer hospital stays and time to ambulation in SPKP group than NPKP group (3.7±0.8 vs 3.4±0.5 and 2.0±0.8 vs 1.6±0.5, $P < 0.05$). In SPKP group, significantly better clinical outcomes at 6- and 12-months follow-up were observed in NPKP group than SPKP group ($P < 0.05$), and NPKP group showed significantly better in vertebral anterior height rates than SPKP group after 6-month follow-up ($P < 0.05$). Moreover, there were significantly more cases of complications in the SPKP group ($P < 0.05$).

Conclusion: Sarcopenia could reduce the clinical effect of percutaneous kyphoplasty, and furthermore. Related studies are needed to verify the effect of sarcopenia on OVCF patients.

Keywords: sarcopenia, percutaneous kyphoplasty, osteoporosis vertebral compression fracture, clinical effect

Introduction

Osteoporotic vertebral compression fracture (OVCF) has a debilitating effect on human health, and its incidence is gradually increasing worldwide. According to Zheng et al, there was a 1.79-fold increase in the incidence of OVCF in patients aged over 50 years in China, rising from 85.21/100,000 in 2013 to 152.13/100,000 person-years in 2017.[1] In a nationwide population-based study of OVCF in South Korea, Choi et al found that the number of OVCF patients increased from 117,361 in 2012 to 139,889 in 2016, with 45% of the OVCF patients being over 70 years of age.[2] Similarly, Cauley et al reported that the prevalence of OVCF was 10.6% in black women and 19.1% in white women aged ≥65 years in the USA.[3] OVCF also poses a huge burden on society. Hopkins et al reported that the average costs of

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patients treated with percutaneous kyphoplasty (PKP) was US$58,986 in inpatient departments and US$32,972 in outpatient departments.[4]

The degeneration of paravertebral muscles and ligaments in older patients with OVCF can lead to a substantial reduction in anterior vertebral height. This, in turn, may result in spinal kyphosis and even spinal sagittal imbalance. Thus, the primary goals of treatment involve restoring vertebral height and spinal realignment, thereby decreasing the time required for ambulation and providing relief from back pain.[5] Percutaneous kyphoplasty (PKP) is currently one of the most common surgical treatments for OVCF, and many studies have reported that patients who undergo PKP achieve satisfactory pain relief and improvement in spinal function. In a study involving 232 patients (87 with osteoporosis and 81 with osteopenia) with single-segment vertebral compression fractures who underwent PKP, Ge et al reported that all patients achieved significant pain relief and kyphotic angle improvement ($P < 0.05$).[6] However, previous studies have reported that some patients may experience varying degrees of residual back pain and vertebral refracture after PKP. In the study of Yu et al that enrolled 236 OVCF patients who underwent PKP and had a minimum 6 months follow-up, 30 patients had residual back pain (VAS score >3.5) at the 6-month follow-up.[7] Li et al reported that of 230 OVCF patients treated with PKP, 30 experienced re-collapse of the surgical vertebra.[8] To date, there is no consensus regarding the precise explanation of the debilitating clinical effects of PKP.

Sarcopenia, a disease characterized by a decline in physical abilities and functionality caused by musculoskeletal conditions, has gradually gained the attention of researchers.[9] Generally, smooth muscle index (SMI) is the most commonly used method to diagnosis sarcopenia (smooth muscle index (SMI): male < 36 cm^2/m^2; female < 29 cm^2/m^2). Bo et al compared the clinical characteristics of 56 OVCF patients with residual back pain and 100 OVCF patients without residual back pain and found that sarcopenia could be a possible explanation for the occurrence of residual back pain after surgery.[10] According to the findings reported by Chen et al, out of a total of 214 OVCF patients who underwent PKP, 74 experienced refracture and 78% had sarcopenia. In contrast, among the other 140 patients who did not experience refracture, only 8% of patients had sarcopenia and underwent PKP.[11] Therefore, it is necessary to explore the effects of sarcopenia in OVCF patients after PKP. However, only few studies have focused on the relationship between sarcopenia and prognosis of patients with OVCF after PKP. We hypothesized that sarcopenia could affect the clinical outcome of OVCF patients. Therefore, this study aimed to compare the clinical outcomes between OVCF patients with and without sarcopenia.

Method

This was a retrospective study of patients with single-segment OVCF treated with PKP. Data were obtained from medical records at Ningbo No. 6 from January 2021 to March 2022. The inclusion criteria were as follows: 1) diagnosis of single-segment OVCF (T-value < −2.5) and sarcopenia (smooth muscle index (SMI): male < 36 cm^2/m^2; female < 29 cm^2/m^2);[12] 2) treated with PKP; 3) available complete clinical data; and 4) having a minimum of 1-year follow-up. The exclusion criteria were as follows: 1) history of spinal surgery; 2) Kummel's disease, spinal deformity, or spinal tumor; 3) diseases that affect bone metabolism, such as chronic renal failure and hyperparathyroidism; 4) severe cardiac and pulmonary dysfunction that does not allow for surgery; and 5) infection and refracture during surgery. A total of 45 patients who met the inclusion criteria were included in the Sarcopenia-PKP group (SPKP group), and 56 patients who underwent PKP for single-segment OVCF without sarcopenia were included in the Normal-PKP group (NPKP group).

All procedures involving human participants were performed in accordance with the ethical standards of the institution and the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. This study was approved by the Research and Ethics Committee of Ningbo No.6 Hospital.

Operation Procedure

All surgical treatments were performed by the same senior surgeon, and patients were treated with unilateral PKP under local anesthesia. The patient was placed in the prone position, the fractured vertebra was confirmed using the C-arm, and the projection of the surgical pedicle was marked on the skin surface. After disinfection and surgical draping, a 0.5 cm incision was made 2 cm lateral to the mark. Then, a percutaneous needle was used to locate the posterolateral aspect of the pedicle, which was then confirmed by fluoroscopy. Subsequently, the puncture needle was inserted when the medial

location of the pedicle on the anteroposterior radiograph aligned with the posterior wall of the vertebral body on the lateral radiograph. Next, the puncture needle was inserted approximately 2 cm forward until it reached the anterior 1/2 to 2/3 of the vertebral body, as confirmed on the lateral radiograph. A working cannula and balloon retractor (<200 psi) were inserted at the anterior 3/4 of the vertebrae. After the fractured vertebrae were reduced, polymethyl methacrylate bone cement was injected via a working cannula under C-arm monitoring. Finally, the working cannula was removed, and the incision was covered with a medical dressing. All patients wore a brace for 1 month after the operation and were encouraged to ambulate with a lumbar brace (Figure 1).

Outcome Evaluation

Baseline data including age, sex, body mass index (BMI), surgery segment, bone mineral density (BMD), and operation-related parameters (operation time, time to ambulation, hospital stay, and surgery segment) were collected from the patients' medical records.

The radiological outcomes were measured by two experienced radiologists as follows. Anterior height (AH) rate of the vertebra: measure the anterior and posterior height of the fractured vertebra in the lateral spinal X-ray, and anterior height rate = anterior height/posterior height*100%. Local kyphosis angle of the vertebra: Cobb angle between the superior and inferior aspect of the fractured vertebra.[13] Regarding clinical outcomes, back pain was assessed using a visual analog scale (VAS; 0, no pain; 10, most severe pain). The Oswestry Disability Index (ODI) and Japanese Orthopaedic Association (JOA) scores were used to evaluate the daily living abilities of patients. MacNab scores were obtained and divided into four categories: excellent, good, fair, and poor.[14] Smooth muscle index: the areas of the ventral abdominal muscle, paraspinal muscle, and psoas muscle were measured on CT images (−29~150 Hounsfield units) at the level of the third lumbar vertebrae.[15] Complications were also assessed.

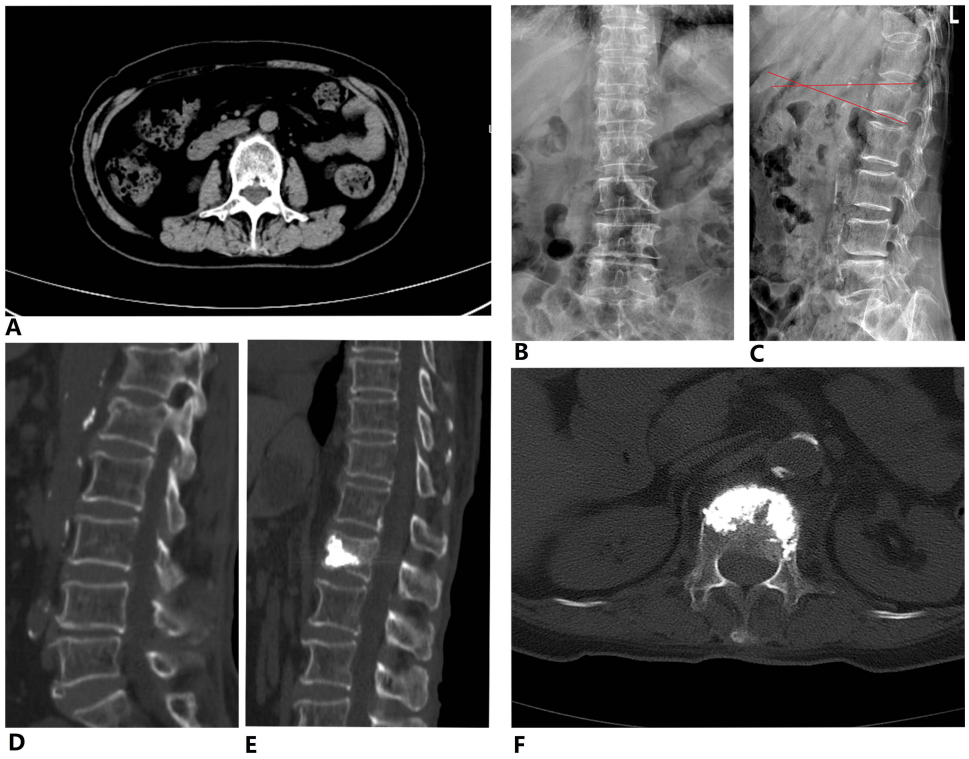

Figure 1 An 84-year OVCF female patient with sarcopenia treated with PKP. (**A**) the CT scan at the level of third lumbar vertebrae, (**B**–**D**) the preoperative X-ray and CT-scan showed L1 compression fracture, and the AH is 66.1%, LKA is 16.4°(Red arrows: Cobb angle between the superior and inferior aspect of the fractured vertebra). (**E** and **F**) the post-operative CT scan showed the post-operative AH is 93.1% and LKA is 6.3°.

Statistical Analysis

The Statistical Package for Social Sciences (version 24.0; IBM Corp., Armonk, New York, USA) was used for statistical analysis. All data are expressed as the mean ± standard deviation. The Shapiro–Wilk test was used to determine the normality of continuous data. Age, BMI, ODI, and JOA measurement data were compared using ANOVA. Categorical data were compared using the χ^2 test. Statistical significance was set at $P < 0.05$.

Results

Baseline Characteristics

A total of 101 patients with OVCF who met our criteria were enrolled, and their medical records were retrospectively reviewed. There were no significant differences in age, sex, operation time, and surgical segment between the 45 patients in the SPKP group and the 56 patients in the NPKP group ($P > 0.05$). Additionally, significantly lower BMI (22.7±2.5 kg/m^2 vs 23.6±2.1 kg/m^2, $p < 0.05$), SMI (28.7±2.5 cm^2/m^2 vs 42.7±3.8 cm^2/m^2, $P < 0.05$), and bone mineral density (−3.7 ±0.6 vs −3.1±0.4, $P < 0.05$) and significantly increased time to ambulation (2.0±0.8 d vs 1.6±0.5 d, $P < 0.05$) and hospital stays (3.7±0.8 d vs 3.4±0.5 d, $P < 0.05$) were observed in the SPKP group compared to the NPKP group. Table 1 presents the baseline characteristics and operation-related outcomes.

Clinical Outcomes

Clinical outcomes are shown in Table 2. There were no significant differences in the VAS, JOA, and ODI scores between the two groups pre-operation ($P > 0.05$). During the follow-up visit, the NPKP group achieved significantly better back pain relief and ODI and JOA scores than the SPKP group ($P < 0.05$). Specifically, at the I and 6 months follow-up visit, the VAS score for back pain in the SPKP group (2.9±0.8 and 1.6±0.5) was significantly higher than that of the NPKP group (1.5±0.5 and 0.8±0.7) ($P < 0.05$). At the final follow-up visit, the NPKP group exhibited significantly lower VAS scores than the SPKP group (0.5±0.5 vs 0.9±0.7, $P < 0.05$). Meanwhile, the NPKP group achieved significant improvements in the ODI and JOA scores compared to the SPKP group at each follow-up visit ($P < 0.05$). Regarding the MacNab score, there were 15 patients were classified in excellent, 20 in good, 8 in fair, and 3 in poor in the SPKP group, whereas 33 patients were classified in excellent, 20 in good and 3 in fair in the NPKP group, and the difference between the two groups was statistically significant ($P < 0.05$).

Table 1 Comparison of Baseline and Operation-Related Outcomes Between Two Groups

	S-PKP (N = 45)	N-PKP (N = 56)	P-value
Age (yr)	69.4±6.3	68.7±7.0	0.62
Gender			0.49
Male	21	25	
Female	24	31	
BMI (kg/m^2)	22.7±2.5	23.6±2.1	0.04$^{\varphi}$
SMI (cm^2/m^2)	28.7±2.5	42.7±3.8	<0.001$^{\varphi}$
Operation time (min)	48.5±4.9	46.3±5.8	0.06
Bone mineral density	−3.7±0.6	−3.1±0.4	0.03$^{\varphi}$
Time to ambulation (d)	2.0±0.8	1.6±0.5	0.008$^{\varphi}$
Hospital stays (d)	3.7±0.8	3.4±0.5	0.03$^{\varphi}$
Segment			0.94
T11	7	10	
T12	15	16	
L1	20	25	
L2	3	5	

Note: $^{\varphi}p<0.05$.

Table 2 Comparison of Clinical Outcomes Between Two Groups

	S-PKP (N = 45)	N-PKP (N = 56)	P-value
VAS			
Preoperative	6.2±0.8	6.0±0.7	0.32
1 month	2.9±0.8	1.5±0.5	<0.001$^{\varphi}$
6 months	1.6±0.5	0.8±0.7	<0.001$^{\varphi}$
12 months	0.9±0.7	0.5±0.5	0.007$^{\varphi}$
ODI			
Preoperative	60.2±6.1	61.2±6.2	0.43
1 month	42.6±3.7	34.5±3.9	<0.001$^{\varphi}$
6 months	28.6±5.7	22.7±4.3	<0.001$^{\varphi}$
12 months	25.8±0.8	18.3±3.5	<0.001$^{\varphi}$
JOA			
Preoperative	12.0±2.6	12.5±3.1	0.47
1 month	17.2±3.0	19.7±2.8	<0.001$^{\varphi}$
6 months	21.4±2.2	24.4±2.9	<0.001$^{\varphi}$
12 months	22.1±1.5	25.9±2.1	<0.001$^{\varphi}$
MacNab			
Excellent	15	33	0.01
Good	20	20	
Fair	8	3	
Poor	3	0	

Note: $^{\varphi}$p<0.05.

Radiological Outcomes

The anterior height rate (47.5±7.5 vs 44.7±8.9°, P > 0.05) and local kyphosis angle (12.8°±5.6° vs 13.1°±5.9°, P < 0.05) were similar between the two groups preoperatively (P < 0.05), and the details are presented in Table 3. Two group achieved satisfactory improvement in AH and LKA after operation, and there was no significant difference in radiological outcomes at the 1-month follow-up visit (86.9±3.3 vs 86.1±4.3 and 4.8±2.1 vs 4.7±2.4, P > 0.05). However, compared to the SPKP group, significantly better AH and LAK maintenance was observed in the NPKP group at the 6- and 12-month follow-up visits.

Complication

Complications were observed in a total of 6 patients in the SPKP group and 1 patient in NPKP group, with a significant difference between two groups (P < 0.05). Four patients had residual back pain, which was successfully managed with oral anti-osteoporosis drug and traditional Chinese medicine treatment (manipulation and acupuncture), and 2 patients

Table 3 Comparison of Radiological Outcomes Between Two Groups

	S-PKP (N = 45)	NPKP (N = 56)	P-value
AH(%)			
Preoperative	47.5±7.5	44.7±8.9	0.1
1 month	86.9±3.3	86.1±4.3	0.26
6 months	79.9±2.9	84.6±3.8	<0.001$^{\varphi}$
12 months	79.9±2.2	81.9±2.6	<0.001$^{\varphi}$
LKA(°)			
Preoperative	12.8±5.6	13.1±5.9	0.26
1 month	4.8±2.1	4.7±2.4	0.71
6 months	7.4±3.5	6.5±3.6	0.01
12 months	8.3±2.9	6.9±3.2	<0.001$^{\varphi}$

Note: $^{\varphi}$p<0.05.

experienced a refracture, which was treated by conservative management. In the NPKP group, one patient developed residual back pain, which was successfully managed with oral anti-osteoporosis drugs.

Discussion

The Pathophysiology of Sarcopenia

In 1993, Evans et al first defined sarcopenia as age-related loss of skeletal muscle mass and bone mineral content, which results in decreased strength and functional capacity.[16] The 2014 guidelines of the European Working Group on Sarcopenia in Older People (EWGSOP's) defined "sarcopenia" as and "severe sarcopenia" as muscle mass with decreased muscle strength and physical function. The recommended diagnostic tools are: 1) Muscle strength and grip strength; 2) Physical function: SARC-Calf, total of 5 times (sitting up time, 6m walking speed, etc.);[17] and 3) Muscle mass: calf circumference measurement, dual-energy X-ray absorption (DXA), bioelectrical impedance analysis (BIA), CT, or MRI body cross-sectional muscle measurement[18] The underlying mechanism of sarcopenia is controversial, and the possible reasons are as follows: 1) Immune regulation disorders in the body, which lead to the excessive production of insulin-like factor-binding protein-3 and −5 (IGFBP-3 and IGFBP-5). This, in turn, results in the increased consumption of insulin-like growth factor 1 (IGF-1), which inhibits the activation of insulin-like growth factor-binding receptors on the surface of muscle cell membranes. Subsequently, the PI3K-Akt-mTOR pathway is downregulated in myocytes, leading to muscle degeneration and atrophy;[19] 2) Systemic inflammatory response: Chronic inflammation leads to the reduced production of myogenin, myogenic factor-5, and MyoD, leading to muscular atrophy and sarcopenia.[20]

The Relationship with OVCF

Sarcopenia is closely associated with OVCF. In a retrospective cross-sectional study on the relationship between sarcopenia and OVCF in elderly women, Zhang et al found that the psoas muscle index in the non-osteoporosis group was significantly higher than that of the osteoporosis group (360.0±98.5 mm^2/m^2 vs 403.0±111.0 mm^2/m^2, $P<0.05$). In addition, 27 of the 57 patients in osteoporosis group and 8 of the 50 patients in non-osteoporosis group had a thoracolumbar fracture ($P < 0.001$). Therefore, they proposed that sarcopenia may be an independent risk factor for OVCF.[21] Additionally, Kajiki et al collected the clinical data of 87 patients and analyzed the relationships between psoas muscle index, bone mineral density, and fracture risk. They found that the psoas muscle index was significantly correlated with BMD and fracture ($r = 0.413$ and $r = -0.545$, both $P < 0.001$).[22]

Some researchers reported that sarcopenia not only had a close correlation with the occurrence of OVCF but also played a role in re-fracture after PKP. Chen et al compared the paraspinal muscle area (multifidus, erector spinae, and psoas major) between 55 patients with re-fracture after surgery for OVCFs and 55 patients without re-fracture and found that there was a significant decrease in the paraspinal muscle area in the re-fracture group ($P < 0.05$).[23] Similarly, Wang et al reported that of 64 of 237 OVCF patients treated with PKP experienced a refracture during the follow-up period, and among these 64 patients, 21 were diagnosed with sarcopenia. After multivariable analysis, sarcopenia was found to be an independent risk predictor of osteoporotic vertebral compression re-fracture (OR, 2.271; 95% CI, 1.069–4.824; $p = 0.033$).[12]

The Effect of Sarcopenia on OVCF Patients

It remains controversial whether sarcopenia has a debilitating effect on the clinical treatment of OVCF patients after surgery. However, some previous studies have reported that sarcopenia plays a role in the prognosis period. Gao et al evaluated the clinical and radiological outcomes of 876 patients (86 of 876 occurred residual back pain) with single-segment OVCF who underwent percutaneous vertebral augmentation and found that paraspinal muscle fatty degeneration was closely related to residual back pain (OR = 12.23; 95% CI 7.81–23.41; $P < 0.001$).[24] Lidar et al analyzed the data of 237 patients with OVCFs who underwent PKP and found that sarcopenia was an independent risk predictor of refracture in OVCF patients after PKP (OR 2.271; 95% CI 1.069–4.824; $P = 0.033$).[25] Overall, clarifying the effect of sarcopenia on the clinical outcomes of patients with OVCF after PKP is of great clinical significance. In this study, we compared clinical and radiological outcomes between the SPKP and NPKP groups. During the 1-year follow-up visit, the NPKP

group showed significant improvement and maintenance of lumbar function (VAS, JOA, and ODI) and radiological outcomes (AH and LKA) and exhibited less complications compared with the SPKP group ($P < 0.05$). Compared to the SPKP group, bone mineral density (−3.7±0.6 vs −3.1±0.6, $P < 0.05$), time to ambulation (2.0±0.8 d vs 1.6±0.5 d, $P < 0.05$), and hospital stay (3.7±0.8 d vs 3.4±0.5 d, $P < 0.05$) were all significantly higher in the NPKP group. At the final visit, the NPKP group achieved significantly better MacNab scores than did the SPKP group ($P < 0.05$). Similarly, Wang et al reported that 77 OVCF patients underwent PKP (34 with sarcopenia and 43 without sarcopenia), and the patients in the non-sarcopenic group had significantly better VAS (1.0 [0.0, 2.0] vs 3.0 [2.0, 4.0], $P < 0.05$) and ODI (15.0 [14.0, 17.0] vs 18.5 [17.0, 22.0], $P < 0.05$) scores than the sarcopenia group. Additionally, the nonsarcopenic group also exhibited a significantly lower ambulation time (1.67±0.84 d vs 2.56±1.13 d, $P < 0.05$) and reduced hospital stay (2.58 ±0.93 d vs 3.94±1.18 d, $P < 0.05$) than the sarcopenic group.

Similarly, paraspinal muscle atrophy and fatty degeneration could be predictors of progressive vertebral collapse, refracture, and mortality in OVCF patients treated with surgery. Osterhoff et al reported that 23 of 191 OVCF patients treated with surgery had secondary symptomatic adjacent OVCF, and these 23 patients with secondary adjacent OVCF showed significantly lower multifidus muscle areas (264±53 mm^2 VS 271±92 mm^2, $P < 0.05$) than the other 168 patients without secondary adjacent OVCF.[26] In summary, Bayram et al reported that among 103 elderly patients who underwent percutaneous vertebral augmentation treatment for OVCF, 51 of them had sarcopenia (PVLI: psoas/lumbar vertebral index < 0.603). During the follow-up period, patients with low PVLI showed significantly higher mortality rates (43.1% vs 0%, $P = 0.001$) than patient with high PVLI.[27]

In conclusion, sarcopenia could have debilitating effects on the clinical treatment of OVCF patients after surgery, probably due to the following reasons. (1) patients diagnosed with sarcopenia often experience reduced mechanical stimulation on their bones due to lower muscle mass and strength, leading to decreased muscle contraction. Thus, the decreased mechanical signals in patients with sarcopenia lead to reduced intercellular communication and secretion of factors that regulate the activity of osteoblasts, the cells responsible for bone formation. Finally, there is progressive loss of bone minerals, resulting in the aggravation of osteoporosis.[28] (2) The vertebra bears increased pressure from the patient's own weight due to the significant decrease in muscle mass and strength. This could be a possible reason why patients with OVCF may experience residual back pain, collapse, and refracture after PKP.[29]

Limitations

This study has some limitations. First, because this was a retrospective, single-center study vulnerable to bias, all eligible patients were identified using predefined inclusion and exclusion criteria to minimize bias. Second, due to the retrospective study design, sarcopenia could only be diagnosed using SMI based on CT scans, and the handgrip strength or the Short Physical Performance Battery (SPPB) score could not be measured.

Data Sharing Statement

The data that support this study are available from the corresponding authors upon request.

Ethical Approval and Consent to Participate

The present study followed the Declaration of Helsinki. Informed consent was waived because of retrospective study, and this study was approved by the Institutional Review Boards and Ethics Committee of Ningbo No.6 Hospital.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no conflicts of interest regarding the publication of this paper.

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