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ORIGINAL ARTICLE

Risk factors of new symptomatic vertebral compression fractures in osteoporotic patients undergone percutaneous vertebroplasty

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Abstract
Purpose This study evaluated the risk factors of new vertebral compression fractures (VCFs) following percutaneous vertebroplasty (PVP).
Methods From June 2005 to January 2011, patients with osteoporotic VCFs (OVCFs) who were treated with PVP and met this study's inclusion criteria were retrospectively reviewed. Observed parameters were age, sex, bone mineral density, body mass index, amount of bone cement, cement leakage into the disk, preoperative kyphosis, preoperative degree of anterior vertebral compression, preoperative degree of middle vertebral compression, kyphosis correction, anterior vertebral height restoration, middle vertebral height restoration, and number of initial symptomatic fractures (levels treated). The data were analyzed by univariate and multivariate analysis for the emergence of new fractures after PVP to determine related risk factors.
Results A total of 182 patients met the inclusion criteria. There were 155 female and 27 male patients with a mean age of 69.7 years (range 49–91 years). The follow-up period was 24–50 months (average 26.4 months). A total of 294 VCFs among 182 patients were observed, 28 new VCFs occurred in 21 patients (21/182, 11.5 %) during the follow-up period. Statistical analysis indicated that higher BMI ($P = 0.004$) and a greater number of initial symptomatic fractures ($P = 0.017$) were significantly associated with new VCFs after PVP. It is the most obvious that the risk of new fractures increased 2.518-fold (95 % CI 1.176–5.395), when the number of initial VCFs increased by one level.
Conclusions The incidence of new symptomatic VCFs after PVP was higher in osteoporotic patients with initial multiple-level fractures.

Keywords Retrospective study · Osteoporotic vertebral compression fracture · Percutaneous verteproplasty · Risk factor

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Introduction

The incidence of osteoporosis has been rising substantially with the aging of the population, and osteoporotic vertebral compression fractures (VCFs) are a major complication. Percutaneous vertebroplasty (PVP) is widely performed in clinical practice because of its advantages in pain relief and partial restoration of vertebral height. New VCFs are common in patients with osteoporosis who have undergone PVP. New VCFs require either reoperation or conservative treatment, reducing patient satisfaction. The incidence of new VCFs (both adjacent and non-adjacent) is reportedly 5.5–52.0 % [1–6]. Lindsay et al. [7] reported that 17.4 % of patients with VCFs (mean age 74 years) developed new fractures within 1 year, which may be related to the natural course of osteoporosis. Voormolen et al. [6] believed that the presence of more than two preexisting VCFs was the only independent risk factor for the development of new VCFs after PVP. However, Lin et al. [8] reputed that an increased risk of VCFs was associated with proximity to the treated vertebra, greater kyphosis correction, and a low body mass index (BMI). Some potential risk factors began

to be suspected, including age, sex, bone mineral density (BMD), BMI, amount of bone cement injected, bone cement leakage, and number of initial symptomatic fractures treated [9, 10]. However, definitive risk factors are inconclusive. The purpose of this study was to investigate the risk factors for and relative risk of new symptomatic VCFs following PVP in patients with osteoporosis.

Materials and methods

All patients treated with vertebroplasty at our institution from June 2005 to January 2011 were retrospectively reviewed. Approval was obtained from our institutional review board. All patients received explanations of the PVP procedure and handling of clinical data. Written informed consent was obtained from each patient.

The L2–L4 vertebrae were selected for BMD measurement. The BMD was measured with dual-energy X-ray absorptiometry (OSTEOCORE 3; MEDILINK, Mauguio, France), and the corresponding T-score was calculated. Each patient's height and weight were recorded to calculate the BMI.

The inclusion criteria were primary osteoporosis with bone density meeting the World Health Organization diagnostic criteria for osteoporosis, pain or local tenderness consistent with imaging findings, no history of steroid use, available preoperative spinal X-ray and magnetic resonance imaging (MRI) results, initial treatment by PVP, new MRI-identified fracture after PVP with no clear history of trauma, and a $\geq$2-year follow-up period.

The exclusion criteria were a non-osteoporotic VCF or compression fracture pressure secondary to other factors, such as pathologic fracture due to metastasis or symptomatic hemangioma; no initial treatment by PVP; preoperative radicular symptoms or symptoms of spinal cord compression; new fracture after PVP with a clear history of trauma or identified without MRI; and a <2-year follow-up period.

Vertebroplasty procedure

PVP was typically offered to patients with refractory pain referable to osteoporotic VCF of the thoracic or lumbar spine as evidenced on MRI. Vertebroplasty was not performed when the following exclusion criteria were met: improvement with conservative management, technical contraindications, and uncorrelated pain.

With the patient in the prone position, local anesthesia (1 % lidocaine) was administered over the skin, subcutaneous tissues, muscular tissues, and periosteum of the targeted pedicle. Bone cement was injected by unilateral or bilateral transpedicular puncture. Blood pressure, oxygen saturation, and heart rate and rhythm were intraoperatively monitored, and low-flow oxygen was administered at 3 L/min. Biplane fluoroscopy was performed in all cases; 13-gauge needles were advanced to the anterior third of the vertebral body and adjusted according to the needle location and depth with biplane fluoroscopic guidance. The volume of bone cement injected was based on the size of the vertebra and degree of vertebral compression and leakage. If the bone cement was not dispersed over the vertebral midline by unilateral puncture on X-ray films, pedicle puncture injection of bone cement was performed on the other side. Otherwise, the surgery was finished.

The cement material was prepared by combining polymethyl methacrylate powder with sterile barium sulfate for opacification, followed by the addition of liquid monomer (Tianjin SyntheticMaterial Research Institute, Tianjin, China). The mixture was injected with either an injector device or 2-mL syringe. Injection was immediately terminated in the event of bone cement dispersion to the posterior one-fourth of the vertebral body on the lateral projection or cement leakage (e.g., intervertebral space, venous, paravertebral, or epidural leakage). After needle removal, strict bed rest was enforced for 24 h, after which the patients were allowed to ambulate. All patients were treated with calcium supplementation and oral bisphosphonates after PVP. A maximum of four vertebral levels were treated in a single session based on the clinician's comfort level.

Parameters observed

Data were collected on age, sex, BMI, BMD (T-score), amount of bone cement, cement leakage into the disk, preoperative kyphosis, preoperative degree of anterior vertebral compression (DAVC), preoperative degree of middle vertebral compression (DMVC), kyphosis correction, anterior vertebral height restoration, middle vertebral height restoration, and number of initial symptomatic fractures (levels treated).

The vertebral kyphosis angle was measured as follows (Fig. 1): The vertebral kyphosis angle was defined as the angle between the upper and lower edges of the VCF (dashed line in Fig. 1) on a lateral X-ray film. The kyphosis correction was calculated as the difference between the postoperative and preoperative kyphosis angles.

The degree of vertebral compression was measured as follows (Fig. 1): The means of the upper and lower posterior vertebral heights adjacent to the VCF on a lateral X-ray film were used to estimate the posterior vertebral height of the VCF. The anterior and middle heights of the VCF were then measured. The DAVC was defined as the ratio of the anterior vertebral height to the estimated posterior vertebral height of the VCF. The DMVC was defined

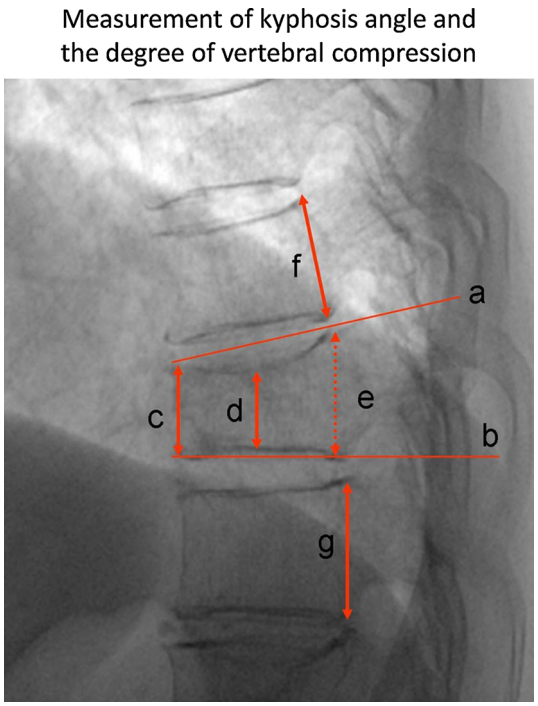

Fig. 1 *a* Upper edge of the vertebral fracture (*dashed line*), *b* lower edge of the vertebral fracture (*dashed line*). The angle between *lines a* and *b* is the vertebral kyphosis angle. *c* Anterior height of the VCF, *d* middle height of the VCF, *f* upper posterior vertebral height adjacent to the VCF, *g* lower posterior vertebral height adjacent to the VCF, *e* estimate of the posterior vertebral height of the VCF (average of *f* and *g*). *c*/*e* = DAVC (%), *d*/*e* = DMVC (%)

as the ratio of the middle vertebral height to the estimated posterior vertebral height of the VCF. VCFs caused by osteoporosis mainly occurred in the anterior and middle columns. Bone cement perfusion was also mainly located in the anterior and middle columns. Thus, the degree of anterior and middle vertebral compression reflected the degree of preoperative compression fracture and postoperative improvement. The anterior vertebral height restoration was defined as the difference between the postoperative and preoperative degrees of anterior vertebral compression, while the middle vertebral height restoration was defined as the difference between the postoperative and preoperative degrees of middle vertebral compression.

New VCF identification criteria

Recurrence in patients with thoracic or low back pain was associated with obvious tenderness in the corresponding parts on physical examination. X-ray examination showed the corresponding parts of the wedge changes in VCFs, and MRI examination confirmed the presence of new fractures. Vertebral marrow edema was shown by low and high signal intensity on T1- and T2-weighted MRI, respectively. MRI was also used to rule out other spinal diseases, including infection and malignancy. The new fracture occurrence time was defined as the duration of time between the end of the operation and the confirmation of a new fracture by MRI examination upon recurrence of thoracic or low back pain.

Statistical analysis

The data were analyzed by univariate and multivariate analysis for the emergence of new fractures after PVP to determine related factors and risk factors. For univariate analysis, quantitative data were collected by *t* tests for two independent samples, and qualitative data were obtained by a Chi-squared test. Logistic regression analysis was used to assess a possible relationship between the occurrence of new VCFs and the following factors: age, sex, BMI, BMD (T-score), amount of bone cement, cement leakage into the disk, preoperative kyphosis, preoperative DAVC, preoperative DMVC, kyphosis correction, anterior vertebral height restoration, middle vertebral height restoration, and number of initial symptomatic fractures (levels treated). All data were processed by SPSS 13.0 statistical software (SPSS, Inc., Chicago, IL, USA), and a $P < 0.05$ was considered statistically significant.

Results

A total of 182 patients met the inclusion criteria; 102 had 1-level fractures, 54 had 2-level fractures, and 26 had ≥3-level fractures. There were 155 female and 27 male patients with a mean age of 69.7 years (range 49–91 years) (Table 1). The follow-up period was 24–50 months (average 26.4 months). In total, 294 VCFs among 182 patients were observed; 187 (63.6 %) of the VCFs involved the T11–L2 vertebral segments (Table 1). No intraoperative or postoperative cardiovascular or cerebrovascular events or pulmonary embolism occurred. Twenty-eight new VCFs occurred in 21 patients (21/182, 11.5 %) during the follow-up period. The BMD T-score was −3.1 to −7.1 (average −4.7) in patients with new VCFs and −2.6 to −8.6 (average −4.5) in patients without new VCFs. The BMI was 15.56–31.16 (average 23.7 kg/m^2) in patients with new VCFs and 13.96–29.78 (average 21.6 kg/m^2) in patients without new VCFs.

The new fracture occurrence time was 1–48 months (average 8.6 months). Of the 21 patients with new fractures, new VCFs occurred in 9 patients (42.9 %) within 3 months after PVP, 11 patients (57.1 %) within 6 months after PVP, and 17 patients (81.0 %) within 12 months after PVP. Of these new fractures, 78.6 % (22/28) and 21.4 % (6/28) occurred in non-adjacent and adjacent vertebrae, respectively (Table 2).

Table 1 Patient characteristics for the entire cohort (mean ± SD)

Patients ($n = 182$)												
Sex (male/female)	*Age (years)*			*BMD (T-score)*			*BMI (kg/m^2)*					
27/155	69.7 ± 9.3			−4.5 ± 1.1			21.8 ± 3.6					
Number of initial fractures												
1 level	*2 levels*			*≥3 levels*								
102	54			26								
Initial VCFs ($n = 294$)												
Cement leakage into disk	*Amount of bone cement (mL)*			*Preoperative kyphosis (°)*			*Kyphosis correction (°)*					
37	3.6 ± 1.1			12.5 ± 6.5			−2.0 ± 2.6					
Preoperative DAVC (%)	*Preoperative DMVC (%)*			*Anterior vertebral height restoration (%)*			*Middle vertebral height restoration (%)*					
68.5 ± 16.7	50.7 ± 14.1			4.6 ± 8.9			9.0 ± 9.4					
Level												
T5	*T6*	*T7*	*T8*	*T9*	*T10*	*T11*	*T12*	*L1*	*L2*	*L3*	*L4*	*L5*
Initial VCFs ($n = 294$)												
3	5	13	20	17	14	31	56	54	46	22	10	3
New VCFs ($n = 28$)												
1	0	0	0	3	3	1	3	6	2	4	3	2

DAVC degree of anterior vertebral compression, *DMVC* degree of middle vertebral compression

The new fracture occurrence rate among the 102 patients with 1-level fractures was 7.8 % (8 patients, 9 fractures), that among the 54 patients with 2-level fractures was 11.1 % (6 patients, 7 fractures), and that among the 26 patients with ≥3-level fractures was 26.9 % (7 patients, 12 fractures) (Table 3). Only 6 of 182 patients had 3 consecutive vertebral fractures: T6/T7/T8/L2 (one patient), T8/T10/T11/T12 (one patient), T12/L1/L2 (three patients), and L2/L3/L4 (one patient).

Among the 294 VCFs, 99 levels (33.7 %) had bone cement leakage and 37 levels (12.6 %) had cement leakage into the disk. No patients had clinical symptoms. Cement leakage into the disk accounted for 37.4 % (37/99) of all cases of bone cement leakage. Among the 252 levels in 161 patients without new fractures, 82 levels (32.5 %) had bone cement leakage; 34 of these 82 levels (41.5 %) showed cement leakage into the disk. Among the 42 levels in 21 patients with new fractures, 17 levels (40.5 %) showed bone cement leakage; 3 of these 17 levels (17.6 %) showed cement leakage into the disk (Table 3). However, only one adjacent VCF with cement leakage into the disk occurred; the remaining adjacent VCFs occurred without cement leakage into the disk.

The two independent samples t test showed that the quantitative data were not statistically significant ($P > 0.05$) except BMI ($P = 0.010$). A Chi-squared test was performed for sex, number of initial symptomatic fractures (levels treated), and cement leakage into the disk, but only the number of initial symptomatic fractures was significantly different ($P = 0.001$). Sex ($P = 0.94$) and cement leakage into the disk ($P = 0.429$) were not significantly different (Table 4). Logistic regression analysis indicated that age, sex, BMD (T-score), amount of bone cement, cement leakage into the disk, preoperative kyphosis, preoperative DAVC, preoperative DMVC, kyphosis correction, anterior vertebral height restoration, and middle vertebral height restoration were not significantly associated with new fractures following PVP ($P > 0.05$). Only BMI and the number of initial symptomatic fractures were significantly associated with new VCFs after PVP ($P < 0.05$). The risk of new fractures increased 1.268-fold (95 % CI 1.077–1.492) when the BMI increased by 1 kg/m^2. The risk of new fractures increased 2.518-fold (95 % CI 1.176–5.395) (Table 5) when the number of initial VCFs increased by one level.

Discussion

Previously reported incidences of new VCFs after PVP are inconsistent because of differences in statistical methods, sample sizes, sample inclusion criteria, and follow-up times. Uppin et al. [11] reported that of 177 patients treated

Table 2 Summary of clinical features of 21 patients with new symptomatic VCF

No.	Sex	Age (years)	BMD (T-score)	BMI (kg/m^2)	Amount of bone cement (mL)	Cement leakage into disk	Initial VCFs	New VCFs	New VCFs occurrence time (months)
1	F	72	−4.6	19.2	4	(+)	T12	T10	20
2	F	82	−5.0	23.4	3	(−)	L2	T5	7
3	F	84	−4.5	28.1	3	(−)	T10	L1	7
4	F	66	−4.2	26.2	6	(−)	L1	L4	1
5	F	67	−3.4	25.2	5	(−)	L1	T12	12
6	F	67	−3.6	27.8	2.5	(−)	L3	L1	23
7	F	53	−4.0	22.6	2.5	(−)	T12	T9	48
8	F	77	−5.0	21.2	2	(−)	T7	T12/L4	13
9	F	73	−4.4	27.1	3/4.5	(−)	T8/11	T12	4
10	F	61	−5.3	26.7	3.6/3	(−)	T9/T12	L2/L3	7
11	F	66	−3.9	19.5	5/1.5	(−)	L1/L2	T9	3
12	F	69	−4.8	24.4	5/3	(+)	T9/T12	L1	2
13	F	76	−5.5	18.7	2/2	(−)	T10/T11	L3	1
14	F	71	−6.1	27.3	2.5/3	(−)	T5/T8	L2	11
15	M	76	−5.4	19.2	4/2/3.5	(−)	T12/L1/L2	L4/L5	1
16	F	66	−4.6	27.1	3/3/3	(+)	T7/T12/L2	L1	4
17	M	58	−5.2	20.1	2.5/3/3	(−)	T11/T12/L2	L3	1
18	F	82	−4.4	15.6	3/5/5	(−)	T12/L1/L3	T11	2
19	M	61	−3.1	24.8	2.5/5/3	(−)	T12/L1/L2	T9/T10/L5	1
20	F	80	−7.1	31.2	2/2/4	(−)	T7/T8/T12	L3/L4	3
21	F	69	−4.8	22.9	2/2/3.5/5	(−)	T6/T7/T8/L2	T10/T12	10

Table 3 Incidence of new fractures and cement leakage

	Patients with new VCF ($n = 21$)	Patients without new VCF ($n = 161$)	Incidence
1 level	8	94	7.8 % (8/102)
2 levels	6	48	11.1 % (6/54)
≥3 levels	7	19	26.9 % (7/26)
Total levels	21	161	11.5 % (21/182)

	Patients with new VCF /SimplePara>(number of initial VCFs, $n = 42$)	Incidence	Patients without new VCF (number of initial VCFs, $n = 252$)	Incidence	Incidence (total)
Cement leakage into disk (A)	3	7.1 % (3/42)	34	13.5 % (34/252)	12.6 % (37/294)
All of cement leakage (B)	17	40.5 % (17/42)	82	32.5 % (82/252)	33.7 % (99/294)
A/B	17.6 % (3/17)		41.5 % (34/82)		37.4 % (37/99)

	Adjacent fractures	Non-adjacent fractures	Incidence
New VCF	6	22	21.4 % (6/28)

with PVP, 22 (12.4 %) developed a total of 36 new vertebral body fractures following treatment. In the present study, the new fracture occurrence rate was 11.5 % (21/182), similar to the above-mentioned results. We found 3-month, 6-month, and 1-year new fracture incidence rates of 42.9 % (9 cases), 57.1 % (11 cases), and 81.0 % (17

Table 4 Characteristics of patients with and patients without new VCF (mean ± SD)

Variable	Patients with new VCF ($n = 21$)	Patients without new VCF ($n = 161$)	P
Sex (male/female)	3/18	24/137	0.94
Age (years)	70.3 ± 8.3	69.7 ± 9.5	0.779
BMD (T-score)	−4.7 ± 0.9	−4.5 ± 1.1	0.421
BMI (kg/m^2)	23.7 ± 4.0	21.6 ± 3. 5	0.010*
Number of initial fractures			
1 level	8	94	0.001*
2 levels	6	48	
≥3 levels	7	19	
Cement leakage into disk	3	32	0.541
Amount of bone cement (mL)	3.5 ± 1.2	3.8 ± 1.1	0.186
Preoperative kyphosis (°)	13.9 ± 3.6	13.0 ± 6.3	0.492
Preoperative DAVC (%)	66.6 ± 11.1	67.4 ± 15.7	0.788
Preoperative DMVC (%)	52.7 ± 11.0	49.6 ± 13.0	0.311
Kyphosis correction (°)	−2.3 ± 2.8	−2.4 ± 2.5	0.770
Anterior vertebral height restoration (%)	4.6 ± 7.0	5.9 ± 8.0	0.493
Middle vertebral height restoration (%)	8.3 ± 8.5	10.1 ± 8.4	0.362

DAVC degree of anterior vertebral compression, *DMVC* degree of middle vertebral compression

* Statistically significant

Table 5 Results of multivariate logistic regression analysis

Variable	Regression coefficient	OR (odd ratio)	P	95 % CI for OR
Sex	−0.369	0.692	0.629	0.155–3.084
Age (years)	0.027	1.027	0.367	0.969–1.090
BMD (T-score)	−0.244	0.784	0.332	0.479–1.282
BMI (kg/m^2)	0.237	1.268	0.004*	1.077–1.492
Amount of bone cement (mL)	−0.129	0.879	0.637	0.516–1.499
Preoperative kyphosis (°)	0.089	1.093	0.330	0.914–1.305
Preoperative DAVC (%)	−0.019	0.981	0.638	0.907–1.062
Preoperative DMVC (%)	0.072	1.075	0.086	0.990–1.167
Kyphosis correction (°)	−0.062	0.940	0.668	0.707–1.249
Anterior vertebral height restoration (%)	−0.011	0.989	0.833	0.896–1.093
Middle vertebral height restoration (%)	0.038	1.039	0.423	0.946–1.141
Cement leakage into disk	−0.437	0.646	0.543	0.159–2.635
Number of initial fractures	0.924	2.518	0.017*	1.176–5.395

DAVC degree of anterior vertebral compression, *DMVC* degree of middle vertebral compression

* Statistically significant

cases), respectively. These results suggest that the first year after the procedure is an important period for the occurrence of new fractures.

Many authors have reported that new fractures in adjacent vertebrae are more common than previously thought. Some researchers have found that among patients who underwent PVP, approximately half of new fractures appeared in adjacent vertebrae [4] and occurred much earlier than in non-adjacent vertebrae. Trout et al. [12] reported that 41.4 % of new vertebral fractures occurred in vertebrae adjacent to the level treated with vertebroplasty, and Lo et al. [1] reported that the proportion of new adjacent-segment fractures was as high as 55.6 %. Because of these reports, more focus has been placed on adjacent vertebral fractures after PVP. Increasingly more attention is being given to the amount of cement injected, cement leakage into the disk, the preoperative kyphosis and degree of compression, the postoperative compression level and

degree of kyphosis correction, and other parameters. The above factors were also considered in our study.

The optimal amount of injected bone cement is controversial. Vertebroplasty alters the load transfer along the anterior spinal column, significantly increasing the fracture risk and ultimately leading to load failure of the untreated adjacent vertebrae [13]. It is generally advocated to inject as much bone cement as possible without leakage to enhance vertebral strength. An overdose would lead to an unevenly distributed load or stress concentration [14–16] and make the vertebrae more vulnerable to fractures [4]. Small doses of bone cement (1–3 mL) were only helpful to reduce the incidence of leakage, not of adjacent VCFs [17]. Even low-modulus bone cement was not found to affect adjacent VCFs [18]. A retrospective study of 660 levels in 357 patients showed that the bone cement dose was irrelevant to the development of new VCFs after PVP [19], which is consistent with the present study. Therefore, the amount of injected bone cement that produces the best therapeutic outcome remains unknown.

A common complication of PVP was bone cement leakage into the intervertebral disk, paraspinal tissues, venous system, and epidural spaces. Cement leakage into a disk was thought to be associated with adjacent VCFs, but not non-adjacent VCFs. Komemushi et al. [20] reported that only cement leakage into the disk was a significant predictor of new vertebral body fracture after vertebroplasty (odds ratio = 4.633). Leakage may exacerbate existing degenerative disk damage, causing a change in the stress distribution in the disk termed the "pillar effect," and decrease the buffering effect. Lin et al. [21] showed that fractures occurred in 58 % of vertebral bodies adjacent to a disk with cement leakage during the follow-up period, but in only 12 % without cement leakage. Patients undergoing PVP should be informed of the possibility and higher risk of new adjacent fractures if cement leaks into the disk [22]. Rho et al. [23] recently reported that the most important risk factors for new VCFs were osteoporosis and cement leakage into the intervertebral disc. But several studies have reported leakage unrelated to new fractures either at adjacent or non-adjacent levels [3, 9, 19, 24]. These findings are consistent with those of the present study, indicating the irrelevance of new VCFs to intradiscal leakage after PVP.

The presence of an association between a new fracture and restoration of the collapsed vertebral height or kyphosis correction is inconclusive. Some studies have shown that mild preoperative wedge deformity and a greater degree of height restoration increased the risk of new symptomatic fractures after vertebroplasty [2, 25]. Each degree of restoration of vertebral kyphosis increased the risk of new fractures by 9 % [8]. Osteoporosis and biomechanical changes were the most important factors for new VCFs after PVP [26]. Actually, the adjacent vertebrae could fracture even without the procedure [27]. Lunt et al. [28] reported that fewer adjacent fractures occurred following kyphotic deformity correction. The present study further confirmed that preoperative kyphosis, the preoperative degree of vertebral compression, kyphosis correction, and the degree of vertebral height restoration are not related to new fractures. Therefore, we speculate that new VCFs after PVP are a natural progression of osteoporosis regardless of surgery. A randomized controlled trial is required to differentiate various risk factors for new VCFs after PVP.

The number of initial symptomatic fractures is considered to be a risk factor for new fractures after PVP. A clinical study found no difference in the incidence of new VCFs between PVP and conservative therapy, and the number of VCFs at baseline was the only risk factor for new VCFs [3]. Delmas et al. [29] found that the baseline VCF severity was the best independent predictor of the risk for new VCFs. Voormolen et al. [6] found that the presence of more than two preexisting VCFs was the only independent risk factor for new VCFs. However, some studies showed that the emergence of new fractures after PVP was unrelated to the number of initial VCFs [20]. The present study confirmed that the greater the number of levels of initial symptomatic fractures, the higher the incidence of new fractures; additionally, the risk of new fractures increased 2.518-fold with the number of initial VCFs.

In theory, new-onset fractures after PVP may be related to the BMD. A low T-score was an important risk factor for subsequent VCFs following PVP [23, 30]. The pillar effect on the adjacent vertebrae may occur more readily at a lower BMD and cause new VCFs after PVP. However, some studies have shown no significant correlation between the T-score and subsequent development of fractures [31], consistent with the present study.

The level at which BMI becomes a risk factor for spinal fracture recurrence remains uncertain. A low BMI was found to be a risk factor for fracture recurrence in the spine or hip [32] and for new VCFs after vertebroplasty [33, 34]. Interestingly, being overweight or obese was found to increase the incidence of vertebral fracture [35]. In the present study, the risk of new fractures increased 1.268-fold per 1-kg/m^2 increase in BMI. Further studies are needed to identify the boundary at which BMI becomes a risk factor for new VCFs after PVP.

There are several limitations in this retrospective study, including the small number of new VCFs, narrow range of BMD T-scores, and focus on new symptomatic fractures. The results may be biased; the actual incidence of new VCFs after PVP could be higher than that observed.

Conclusion

The incidence of new symptomatic VCFs after PVP was higher in osteoporotic patients with initial multiple-level fractures. The number of initial symptomatic fractures was an important risk factor for new VCFs. Age, sex, BMD T-score, amount of bone cement, cement leakage into the disk, preoperative kyphosis, preoperative DAVC, preoperative DMVC, kyphosis correction, anterior vertebral height restoration, and middle vertebral height restoration did not increase the risk of new fractures after PVP.

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Conflict of interest None.

References

1. Lo YP, Chen WJ, Chen LH et al (2008) New vertebral fracture after vertebroplasty. J Trauma 65:1439–1445
2. Lee WS, Sung KH, Jeong HT et al (2006) Risk factors of developing new symptomatic vertebral compression fractures after percutaneous vertebroplasty in osteoporotic patients. Eur Spine J 15:1777–1783
3. Klazen CA, Venmans A, de Vries J et al (2010) Percutaneous vertebroplasty is not a risk factor for new osteoporotic compression fractures:results from VERTOS II. Am J Neuroradiol 31:1447–1450
4. Chosa K, Naito A, Awai K (2011) Newly developed compression fractures after percutaneous vertebroplasty: comparison with conservative treatment. Jpn J Radiol 29:335–341
5. Tanigawa N, Kariya S, Komemushi A et al (2011) Percutaneous vertebroplasty for osteoporotic compression fractures:long-term evaluation of the technical and clinical outcomes. Am J Roentgenol 196:1415–1418
6. Voormolen MH, Lohle PN, Juttmann JR et al (2006) The risk of new osteoporotic vertebral compression fractures in the year after percutaneous vertebroplasty. J Vasc Interv Radiol 17:71–76
7. Lindsay R, Burge RT, Strauss DM (2005) One year outcomes and costs following a vertebral fracture. Osteoporos Int 16:78–85
8. Lin WC, Cheng TT, Lee YC et al (2008) New vertebral osteoporotic compression fractures after percutaneous vertebroplasty: retrospective analysis of risk factors. J Vasc Interv Radiol 19:225–231
9. Lin WC, Lee YC, Lee CH et al (2008) Refractures in cemented vertebrae after percutaneous vertebroplasty:a retrospective analysis. Eur Spine J 17:592–599
10. Tseng YY, Yang TC, Tu PH et al (2009) Repeated and multiple new vertebral compression fractures after percutaneous transpedicular vertebroplasty. Spine (Phila Pa 1976) 34:1917–1922
11. Uppin AA, Hirsch JA, Centenera LV et al (2003) Occurrence of new vertebral body fracture after percutaneous vertebroplasty in patients with osteoporosis. Radiology 226:119–124
12. Trout AT, Kallmes DF, Kaufmann TJ (2006) New fractures after vertebroplasty: adjacent fractures occur significantly sooner. Am J Neuroradiol 27:217–223
13. Fahim DK, Sun K, Tawackoli W et al (2011) Premature adjacent vertebral fracture after vertebroplasty:a biomechanical study. Neurosurgery 69:733–744
14. Molloy S, Riley LH 3rd, Belkoff SM (2005) Effect of cement volume and placement on mechanical-property restoration resulting from vertebroplasty. Am J Neuroradiol 26:401–404
15. Mudano AS, Bian J, Cope JU et al (2009) Vertebroplasty and kyphoplasty are associated with an increased risk of secondary vertebral compression fractures: a population -based cohort study. Osteoporos Int 20:819–826
16. Molloy S, Mathis JM, Belkoff SM (2003) The effect of vertebral body percentage fill on mechanical behavior during percutaneous vertebroplasty. Spine (Phila Pa 1976) 28:1549–1554
17. Cyteval C, Thomas E, Solignac D et al (2008) Prospective evaluation of fracture risk in osteoporotic patients after low cement volume vertebroplasty. J Radiol 89:797–801
18. Boger A, Heini P, Windolf M et al (2007) Adjacent vertebral failure after vertebroplasty: a biomechanical study of low-modulus PMMA cement. Eur Spine J 16:2118–2125
19. Al-Ali F, Barrow T, Luke K (2009) Vertebroplasty: what is important and what is not. Am J Neuroradiol 30:1835–1839
20. Komemushi A, Tanigawa N, Kariya S et al (2006) Percutaneous vertebroplasty for osteoporotic compression fracture:multivariate study of predictors of new vertebral body fracture. Cardiovasc Intervent Radiol 29:580–585
21. Lin EP, Ekholm S, te Hiwatashi A et al (2004) Vertebroplasty: cement leakage into the disc increases the risk of new fracture of adjacent vertebral body. Am J Neuroradiol 25:175–180
22. Chen WJ, Kao YH, Yang SC et al (2010) Impact of cement leakage into disks on the development of adjacent vertebral compression fractures. J Spinal Disord Tech 23:35–39
23. Rho YJ, Choe WJ, Chun YI (2012) Risk factors predicting the new symptomatic vertebral compression fractures after percutaneous vertebroplasty or kyphoplasty. Eur Spine J 21:905–911
24. Lee KA, Hong SJ, Lee S et al (2011) Analysis of adjacent fracture after percutaneous vertebroplasty: does intradiscal cement leakage really increase the risk of adjacent vertebral fracture. Skeletal Radiol 40:1537–1542
25. Kim SH, Kang HS, Choi JA et al (2004) Risk factors of new compression fractures in adjacent vertebrae after percutaneous vertebroplasty. Acta Radiol 45:440–445
26. Movrin I, Vengust R, Komadina R (2010) Adjacent vertebral fractures after percutaneous vertebral augmentation of osteoporotic vertebral compression fracture: a comparison of balloon kyphoplasty and vertebroplasty. Arch Orthop Trauma Surg 130:1157–1166
27. Lindsay R, Silverman SL, Cooper C et al (2001) Risk of new vertebral fracture in the year following a fracture. JAMA 285:320–323
28. Lunt M, O'Neill TW, Felsenberg D et al (2003) European Prospective Osteoporosis Study Group Characteristics of a prevalent vertebral deformity predict subsequent vertebral fracture: results from the European Prospective Osteoporosis Study (EPOS). Bone 33:505–513
29. Delmas PD, Genant HK, Crans GG et al (2003) Severity of prevalent vertebral fractures and the risk of subsequent vertebral and nonvertebral fractures: results from the MORE trial. Bone 33:522–532
30. Lu K, Liang CL, Hsieh CH et al (2012) Risk factors of subsequent vertebral compression fractures after vertebroplasty. Pain Med 13:376–382
31. Li YA, Lin CL, Chang MC et al (2012) Subsequent vertebral fracture after vertebroplasty: incidence and analysis of risk factors. Spine (Phila Pa 1976) 37:179–183
32. Thomas T, Barou O, Vico L et al (1999) Recurrence of vertebral fracture with cyclical etidronate therapy in osteoporosis: histomorphometry and X-Ray microanalysis evaluation. J Bone Miner Res 14:198–205

33. Zhang Z, Fan J, Ding Q et al (2013) Risk factors for new osteoporotic vertebral compression fractures after vertebroplasty a systematic review and meta-analysis. J Spinal Disord Tech 26:E150–E157
34. Ahn Y, Lee JH, Lee HY et al (2008) Predictive factors for subsequent vertebral fracture after percutaneous vertebroplasty. J Neurosurg Spine 9:129–136
35. Tanaka S, Kuroda T, Saito M et al (2013) Overweight/obesity and underweight are both risk factors for osteoporotic fractures at different sites in Japanese postmenopausal women. Osteoporos Int 24:69–76