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A Study of Risk Factors for Early-Onset Adjacent Vertebral Fractures After Kyphoplasty

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Abstract

Study Design: Retrospective study.

Objectives: To elucidate risk factors for early-onset (2 months after initial kyphoplasty) adjacent vertebral fracture (EO-AVF) after kyphoplasty.

Methods: A total of 108 vertebral bodies (95 patients) were included in this study. We examined patient backgrounds, the spinal level of EO-AVFs, surgery-related factors, and imaging findings. We divided the cases into 2 groups: patients with EO-AVF and patients without EO-AVF. Univariate, correlation, and multivariate analyses were conducted to reveal the risks factors for EO-AVFs for these 2 groups.

Results: EO-AVFs developed in 28 vertebral bodies; they did not develop in 80 vertebral bodies. The overall EO-AVF incidence rate was 26%. The spinal level was the thoracolumbar junction for 93% of patients and another level for 7%, thus demonstrating the concentration of EO-AVFs in the thoracolumbar junction. For patients without EO-AVF and those with EO-AVF, there were significant differences in age (76 and 80 years, respectively), preoperative vertebral angles (VAs) (17.8° and 23°, respectively), and corrected VAs (7.3° and 12.7°, respectively). Significant differences were not observed for other factors. Pearson's correlation coefficient was 0.661 ($P < .000$), thereby showing a significantly positive correlation between preoperative VAs and corrected VAs. Logistic regression analysis indicated that age (odds ratio, 1.112; 95% CI, 1.025-1.206) and preoperative VAs (odds ratio, 1.08; 95% CI, 1.026-1.135) were covariates and that the presence of an EO-AVF was a dependent variable. Therefore, both were predictable risk factors for EO-AVFs.

Conclusion: Age, preoperative VAs, and corrected VAs are risk factors for EO-AVFs after kyphoplasty.

Keywords
kyphoplasty, osteoporosis, adjacent fracture, minimally invasive surgery, complication

Introduction

Osteoporotic vertebral fractures (OVFs) are a major problem in an aging society. Epidemiological data in Japan have indicated that approximately 30% of women in their 70s develop OVFs.[1] Treatment for symptomatic OVFs during the acute or subacute period includes conservative therapy, spinal instrumentation surgery, and cement augmentation. Kyphoplasty is a minimally invasive treatment for painful OVFs that offers instant pain relief and improved quality of life.[2-4] Compared with percutaneous vertebroplasty (PV), balloon kyphoplasty (BKP) has the advantages of a low incidence of cement extravasation and the potential to restore vertebral body (VB) height after the initial surgery.[5] However, a higher rate of adjacent vertebral fractures

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(AVFs) within 2 months after BKP (defined as early-onset AVFs [EO-AVFs]) has been reported, which is distinct from the rate of subsequent OVFs occurring naturally.[6] Furthermore, the incidence of EO-AVFs after BKP is higher than that after PV.[7]

In 2004, Fribourg et al[6] reported that BKP-treated vertebrae had a higher incidence of subsequent fractures than did untreated osteoporotic fractures occurring naturally. Furthermore, in the aforementioned report, the Kaplan-Meier survival curve showed a high incidence of subsequent fractures within 2=months after kyphoplasty. Most of these fractures that developed within 2 months after surgery were at the spinal level adjacent to the kyphoplasty-treated vertebra. Interestingly, beyond 2 months postoperatively, fractures tended to occur at a spinal level remote from the treated vertebra. On the basis of previous findings of different incidence rates and lesion development, it was suggested that different pathologies might exist during the 2 months postoperative period.[6]

Several studies have examined fractures in adjacent areas that were related to vertebroplasty/kyphoplasty, and the risk factors were as follows: rheumatoid arthritis, cardiovascular disease, preoperative segmental kyphosis observed on conventional X-ray (Xp) images, age, anterior vertebral height, level-specific *T*-score, bone mineral density from L2 to L4, and intradiscal cement extravasation.[8-12] However, differences in patient background factors and observation periods at least more than 6 months have produced widely varying risk factors for AVF. There are few reports on the risk factors for EO-AVFs. Our research assessed the types of factors (including previously reported risk factors for AVFs) that affected the development of EO-AVFs, such as patient background, spinal level, surgical procedure, and radiographic features.

Materials and Methods

Study Design

A retrospective analysis of 148 VBs in 127 patients with OVFs treated with kyphoplasty (Kyphon Medtronic) was performed at a single spine center between April 2012 and January 2016. Forty VBs (32 patients) were excluded for the following reasons: tumor-related bone fractures; multiple myeloma diagnosed after surgery (1 patient); previous spinal surgery (3 patients); rheumatoid arthritis (3 patients); Xp images could not be obtained with the patient in the standing position preoperatively/postoperatively (8 patients); additional spine surgery (decompression because of lumbar spinal canal stenosis) after initial BKP (7 patients); loss to follow-up (7 patients); previous fracture adjacent to the index vertebra detected on magnetic resonance imaging (MRI) before surgery (2 patients); and fall after surgery (1 patient). The remaining 108 affected VBs (95 patients) were divided into those with (EO-AVF group) and those without an EO-AVF (non-EO-AVF group), which was defined as an AVF occurring within 2 months after BKP. The institutional review board at our institution approved this study, and written informed consent was obtained from each patient before study participation or surgery.

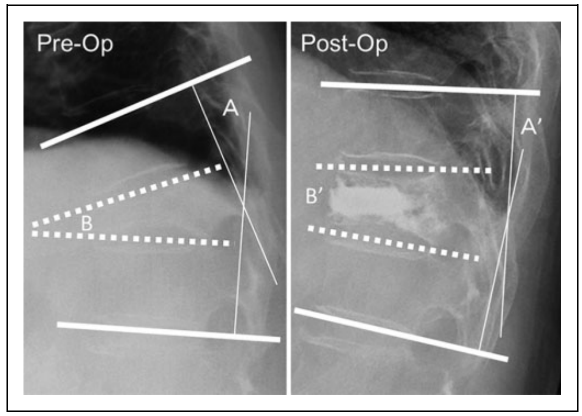

Figure 1. Radiographic variables for preoperative (left) and postoperative (right) X-ray radiography (posture: standing, lateral view). X-p images was obtained preoperatively and within 1 week and 2 months postoperatively. All X-p images were taken with the patient standing. A and B are the preoperative segmental and vertebral angles, respectively; and A′ and B′ are the postoperative segmental and vertebral angles, respectively. The corrected segmental angle is calculated as A minus A′, and the corrected vertebral angle as B minus B′. The kyphotic angle has a positive value and the lordotic angle has a negative value.

Clinical Course and Surgical Procedure

All patients were first treated with conservative therapy such as a brace and pain killers and had a mean duration of approximately 2 months from the development of symptoms to initial surgery (Table 2). To assess the severity of the vertebral fracture, MRI, computed tomography (CT), and Xp (Figure 1) were performed preoperatively. Cases involving neurological symptoms derived from segmented bony fragments compressing the spinal cord or cauda equine were considered contraindicated for BKP.[13] All treated vertebrae had the same morphology, defined as “compression type,” according to the thoracolumbar injury severity score.[14]

All surgeries were performed under general anesthesia using a previously described kyphoplasty technique.[2] A G-shaped fluoroscopic device was used to identify an appropriate entry point, ensure adequate placement of needles, and visualize cement extravasation. A bilateral transpedicular approach was used while inserting and withdrawing the guidewire, obturator, and cannula for all cases. A balloon was inflated slowly while the intervertebral body pressure was monitored until it reached 220 psi or until adequate vertebral height restoration was achieved. Cement was injected until it reached one-third of the anterior-posterior vertebral diameter from the posterior vertebral wall or until cement extravasation appeared. Balloon/cement volume, operative time, and blood loss were recorded. Neurophysiological monitoring was used to determine whether additional laminectomy was necessary because of extravasation of cement. In this series, no case required additional laminectomy at the same time as BKP.

Starting from the day after surgery, patients wore a hard or soft thoracic lumbar brace for 3 months. Osteoporosis drugs were recommended perioperatively for patients who were not already using these drugs.

Risk Factors Associated With Patient Background

Many reports have identified background risk factors for fractures in patients with osteoporosis.[15-21] In this study, age, body mass index, the degree of osteoporosis (bone mineral density and *T*-score in the whole femoral neck and lumbar lesion in L2-L4), comorbidities, perioperative use of osteoporosis drugs, and time after the initial injury were evaluated. The degree of osteoporosis was assessed by dual-energy X-ray absorptiometry (DPX-BRAVO; GE Health Care). Comorbidities included diabetes mellitus, cardiovascular diseases, cerebrovascular diseases, and dialysis treatment for diseases that may lead to bone fragility.[15]

Radiographic Measurements

Radiographic assessments were performed. Xp images were obtained at 7 days and 2 months postoperatively, and CT images were obtained after 7 days to evaluate the cement spread in the vertebrae, extravasation of cement, and EO-AVF. Preoperative and postoperative Xp images were obtained with the patient in the standing position, and the segmental (lordosis/kyphosis) angle and vertebral angle (VA) were measured in the lateral view (Figure 1).

The corrected angle was defined as the degree of correction angle that was obtained by subtracting the postoperative angle from the preoperative angle. For example, the corrected VA was calculated as the preoperative VA minus postoperative VA. The kyphotic angle had a positive value and the lordotic angle had a negative value. CT was used to check the appearance of cement extravasation in the vertebral disc space. An EO-AVF was defined as a new vertebral fracture on the cephalic or caudal side of the BKP-treated VB that developed within 2 months after the initial surgery. An EO-AVF was diagnosed based on the Xp image using the semiquantitative method[22] or based on the appearance of new bone marrow edema on MRI.[23]

Statistical Analysis

The univariate analysis used the chi-square test, Fisher exact test, and Mann-Whitney *U* test to evaluate the patient background data and radiographic measurement. Subsequent analyses were conducted for each significant factor (factors evaluated as $P < .05$ according to the univariate analysis) to reveal confounders using the Pearson correlation analysis. If the variable had $P < .05$ according to the Pearson correlation analysis, then it was assessed as a confounder and not used in the final logistic regression analysis. After minimizing the effects of confounders, predictable risk factors significantly associated with EO-AVFs were identified in the logistic regression analysis, and the probability of EO-AVFs was calculated for each condition. An additional Hosmer-Lemeshow test was performed to calculate the accuracy of this logistic regression analysis. All calculations were performed using SPSS version 24 (IBM Corp). $P < .05$ was considered significant in all analyses.

Table 1. Demographic Data for 108 Kyphoplasty Procedures and Occurrence of Early-Onset Adjacent Vertebral Fracture (EO-AVF).

Item	Thoracolumbar (T10-L2)	The Other Lesion (T4-T9) (L3-L5)
Number of treated vertebrae	93	15
Incidence of EO-AVF, n (%)	26 (28)	2 (13)
Days to EO-AVF, mean ± SD	26 ± 14	42 ± 20
Side of EO-AVF cranial, n (%)	15 (58)	0 (0)
Caudal, n (%)	9 (35)	2 (100)
Cranial and caudal, n (%)	2 (8)	0 (0)

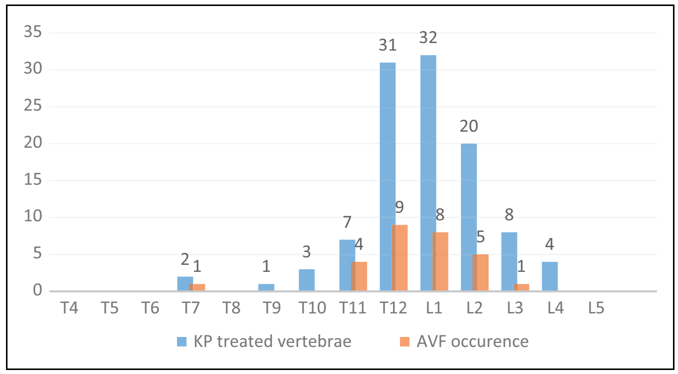

Figure 2. Distributions for involvement of spinal level and prevalence of adjacent vertebral fracture (AVF). The horizontal axis shows spinal levels and the vertical axis shows the numbers of vertebral fractures. There was a high concentration of vertebral fractures at the thoracolumbar level (T10-L2). AVF is likely to be observed at the thoracolumbar level, compared to the lumbar level.

Results

Patient Demographics and Baseline Characteristics

A total of 108 BKP-treated VBs in 95 patients were included in the study. The EO-AVF group included 28 VBs (25 patients), and the non-EO-AVF group included 80 VBs (70 patients). The overall AVF incidence was 26% (28/108). The rates for the thoracolumbar level (T10-L2) and other spinal levels (T4-9 and L3-L5) were 28% (26/93) and 13% (2/15), respectively (Table 1, Figure 2). The incidence of EO-AVFs was higher in the thoracolumbar region, with rates of 57% at T11 and 29% at T12, compared with 12% at L3 and 0% at L4 in the lumbar vertebrae.

Demographic data and comorbidities are listed in Table 2. Patients with EO-AVFs were significantly older than those without EO-AVFs (80 ± 5 vs 76 ± 7 years; $P = .02$), but

Table 2. Background Data for Patients Treated With Kyphoplasty Who Did or Did Not Develop Early-Onset Adjacent Vertebral Fracture (EO-AVF).

Item	EO-AVF	Non-EO-AVF	P^a
Vertebral bodies	28	80	—
Patients, n	25	70	—
Age, years, mean ± SD	80 ± 5.2	76 ± 7.2	**.02**
Sex, male/female, n	8/20	26/54	.23
Body mass index, kg/m^2, mean ± SD	21 ± 3	21 ± 4	.58
Period before operation, days, mean ± SD	82 ± 71	75 ± 70	.33
TLICS score, mean ± SD	1.4 ± 0.9	1.7 ± 1.5	.74
Bone mineral density: Hip, g/cm^2, mean ± SD	0.7 ± 0.1	0.7 ± 0.1	.76
T-score (hip)	−2.2 ± 0.8	−2.1 ± 1.2	.76
Bone mineral density: L2-4, g/cm^2, mean ± SD	0.9 ± 0.1	0.9 ± 0.2	.92
T-score (L2-4)	−2.1 ± 1.2	−2.2 ± 1.2	.75
Preoperative use of osteoporosis drugs, %	25	41	.09
Postoperative use of osteoporosis drugs, %	86	82	.45

Abbreviation: TLICS score, Thoracolumbar Injury Classification and Severity score.
[a] *P* value in boldface indicates statistical significance ($P < .05$).

Table 3. Comorbidities in Patients With Osteoporosis Who Were Treated With Kyphoplasty and Did or Did Not Develop Early-Onset Adjacent Vertebral Fracture (EO-AVF).

Comorbidity	EO-AVF	Non-EO-AVF	*P*
Diabetes mellitus, %	18	18	.59
Cardiovascular disease, %	32	48	.1
Cerebrovascular disease, %	18	18	.59
Dialysis, %	4	6	.6

body mass index, sex, comorbidities, and preexisting osteoporosis did not differ significantly between these groups (Tables 2 and 3). Perioperative use and postoperative use of osteoporosis drugs were not different between the groups; however, the treatment periods for osteoporosis were not available.

Radiographic Measurements

Patients with EO-AVFs had significantly higher preoperative VAs (23° ± 9.8° vs 17.8° ± 9.6°; $P = .009$) and corrected VAs (12.7° ± 8.4° vs 7.3° ± 7.7°; $P = .004$) compared with those without EO-AVFs. No other radiographic factors differed significantly between the 2 groups (Table 4).

Surgical Variables

The average balloon injection volumes were 5.7 ± 1.1 and 5.8 ± 1.3 mL ($P = .6$) and the average cement injection volumes were 6.0 ± 1.1 and 6.1 ± 1.6 mL ($P = .82$) for patients with and without EO-AVFs, respectively. There were no significant differences in surgical variables between the 2 groups.

Table 4. Radiographic Parameters in Patients Treated With Kyphoplasty Who Did or Did Not Develop Early-Onset Adjacent Vertebral Fracture (EO-AVF).

Parameter	EO-AVF	Non-EO-AVF	P^a
Cement leakage into disc, %	11	16	.75
Preoperative vertebral angle, deg, mean ± SD	23 ± 9.8	17.8 ± 9.6	**.009**
Postoperative vertebral angle, deg, mean ± SD	10.7 ± 6.5	9.4 ± 8.0	.12
Corrected vertebral angle, deg, mean ± SD	12.7 ± 8.4	7.3 ± 7.7	**.004**
Preoperative segmental angle, deg, mean ± SD	27.3 ± 13.2	22.4 ± 17	.56
Postoperative segmental angle, deg, mean ± SD	18.9 ± 11	16.3 ± 15	.78
Corrected segmental angle, deg, mean ± SD	8.3 ± 8.3	6 ± 6	.42

[a] *P* values in boldface indicate statistical significance ($P < .05$).

Confounders and Logistic Regression Analysis

The univariate analysis of background factors and radiographic parameters showed significant differences in age, preoperative VA, and corrected VA for patients with and without EO-AVFs. To eliminate confounders before the multivariate analysis, we checked each variable using the Pearson correlation analysis. There was a significant positive correlation between preoperative VA and corrected VA ($r = 0.661$; $P < .001$) (Figure 3), but not between age and preoperative VA ($r = -0.112$; $P = .247$) or corrected VA ($r = -0.22$; $P = .824$). On the basis of these results, binary logistic regression analysis was performed with age and preoperative VA as covariates and EO-AVF as the dependent variable. Both age (odds ratio [OR], 1.112; 95% confidence interval [CI], 1.025-1.206) and preoperative VA (OR, 1.08; 95% CI, 1.026-1.135) emerged as independent predictors of EO-AVFs (Table 5). Results of the logistic analysis indicated that the probabilities of EO-AVFs were as follows: age in the 70s and preoperative VAs of 20°, 25°, and 30° were associated with probabilities of 12%, 17%, and 23%, respectively; age in the 80s and preoperative VAs of 20°, 25°, and 30° were associated with probabilities of 29%, 37%, and 46%, respectively. The predicted accuracy of this logistic analysis was 77% according to the Hosmer-Lemeshow test ($P = .405$ and $P \geq .05$).

Discussion

Kyphoplasty is a minimally invasive procedure for OVFs that quickly alleviates pain and improves quality of life.[2-4] AVFs are a major complication of BKP that lead to recurrent back pain and poor outcomes. Papanastassiou et al[24] conducted a meta-analysis to compare the treatment effects of BKP and PV and the effects of nonsurgical treatment. It was revealed

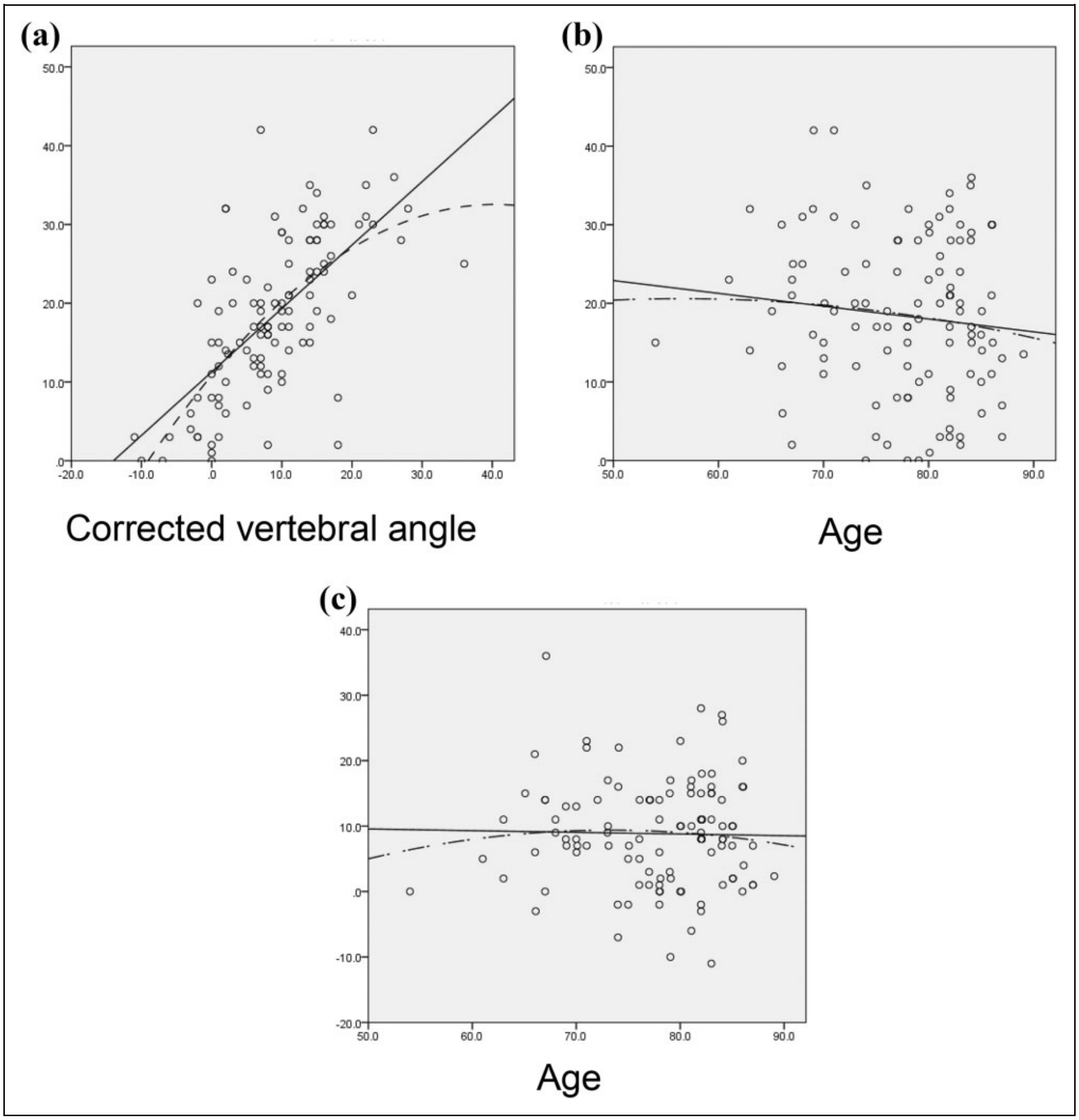

Figure 3. Pearson correlation analysis for variables with a significant difference between the early-onset adjacent vertebral fracture (EO-AVF) and non-EO-AVF groups. (a) The corrected and preoperative vertebral angles had a significant positive correlation ($r = 0.661$, $P < .001$). (b) Preoperative vertebral angle and age were not significantly correlated ($r = -0.112$; $P = .247$). (c) Corrected vertebral angle and age were not significantly correlated ($r = -0.22$; $P = .824$).

Table 5. Results of Logistic Regression Analysis for Age and Preoperative Vertebral Angle (VA) as Risk Factors for Early-Onset Adjacent Vertebral Fracture (EO-AVF).

	β	Odds Ratio	*P*	95% CI
Age	0.106	1.112	.01	1.025-1.206
Preoperative VA	0.076	1.079	.003	1.026-1.135

that subsequent fractures (adjacent and not adjacent) occurred more frequently in those who underwent nonsurgical management (22%) than in those who underwent PV (11%) and BKP (11%). In terms of subsequent fractures, operative management of OVFs can potentially reduce the incidence rate. However, subsequent fracture etiology is affected by various mechanisms such as spinal level, history of osteoporosis drug use, age, comorbidities, follow-up period, magnitude of OVF, and others. Focusing on the early period and the adjacent spinal level of developing fractures, Fribourg et al[6] reported that BKP-treated vertebrae had a higher incidence of subsequent fractures compared with untreated osteoporotic fractures that occurred naturally. Furthermore, most fractures developed within 2 months after surgery at the spinal level adjacent to the kyphoplasty-treated vertebra. Interestingly, beyond 2 months postoperatively, fractures tended to occur at a spinal level remote from the treated vertebra. However, the incidence of adjacent fractures with different timing or locations may result from an acute increase in the mechanical stiffness of vertebrae after cement augmentation. Most studies of AVFs after kyphoplasty have involved an observation period of more than 6 months; therefore, the incidence rate includes subsequent fractures due to primary osteoporotic bone fragility.[10] During shorter-term evaluations, preoperative VAs were observed as a risk factor for EO-AVFs,[8,25] similar to the findings of our study. Therefore, the timing of the evaluation of the AVF incidence is important for distinguishing between the unique pathology of BKP and subsequent OVFs.

By focusing on the other variables reported as risk factors for AVFs (ie, osteoporosis and intradiscal cement leakage), the current study also revealed that there were no differences in the preexisting osteoporosis degree (such as bone mineral density and *T*-score for the hip or L2-4) between the EO-AVF group and non-EO-AVF group. These findings suggested that the bone mineral density and *T*-score of the hip and L2-4 could not be used to predict EO-AVFs. However, a previous report suggested that level-specific *T*-scores have the potential to predict AVFs,[9] which also may be related to EO-AVFs. Intradiscal cement extravasation has also been reported as a risk factor because it mechanically compresses the adjacent vertebral endplates, thereby creating the risk for AVFs[26,27]; therefore, it is still controversial.[11,28] In our study, the prevalence of extravasation of intradiscal cement was 11% in the EO-AVF group and 16% in the non-EO-AVF group. These results suggested that intradiscal cement extravasation is not a major risk factor for EO-AVF. However, for 1 patient, an EO-AVF developed due to cement extravasation of the anterior part of the VB. Jesse et al[12] reported that cement endplate extravasation isolated to the anterior one-third of the VB was associated with significantly higher odds of AVFs after PV or kyphoplasty in patients with osteoporosis. Therefore, cement extravasation of the anterior part of the VB should be avoided.

Frankel et al[7] found that the incidence of kyphoplasty-related AVFs (25%) was higher during the 3 months after surgery compared with after PV (0%). In this series, the amount of cement injected was significantly larger with BKP than with PV (4.65 vs 3.78 mL; $P = .014$); otherwise, BKP and PV were performed similarly in terms of the cement injected into the fractured VB. Solid cement augmentation may cause mechanical environmental changes in an adjacent segment, resulting in the treated vertebrae becoming stiffer than osteoporotic adjacent vertebrae. Therefore, cement augmentation related to increased stiffness in an adjacent component such as vertebrae and intervertebral discs may be involved in the pathology of AVFs and intervertebral disc degeneration.[29-32] These reports suggested that kyphoplasty evokes marked changes in treated and adjacent vertebrae during the early phase of treatment. Therefore, we hypothesized that the preoperative VAs and dynamic mechanical changes are related to the amount of injected cement. To investigate this, we designed a retrospective study in which an EO-AVF was defined as occurring within 2 months after BKP. Initially, we assumed that a difference in the amount of cement injected would affect the prevalence of EO-AVFs; however, our results showed no significant difference in cement amounts between patients with and without EO-AVFs.

Subsequent fractures of the spine are common in patients with osteoporosis who develop initial fractures.[33] Frankel et al[34] showed that the thoracolumbar region had a higher rate of subsequent fractures than other spinal levels during a mean follow-up period of 2.9 years. Females with prevalent fractures at the thoracolumbar junction had at least one new fracture along the spine, and 40.3% had new adjacent-level fractures.[34] We found a higher rate of EO-AVFs in the thoracolumbar junction than at the lumbar level, which is similar to the findings of natural subsequent fractures in patients with osteoporosis. We assumed that these similar findings for EO-AVFs and natural osteoporotic fractures resulted from the mechanical force concentrated in thoracolumbar lesions.

In the current study, for patients with and without EO-AVFs, radiographic parameters, surgical variables, comorbidities related to natural osteoporotic fractures, and history of osteoporosis treatment were examined. A multivariate analysis showed that age and preoperative VA were independent predictors of EO-AVFs. Because the cement and balloon volumes were similar in patients with and without EO-AVFs, the effects of the preoperative VA are particularly significant. These results showed that ballooning has a high potential for restoring vertebrae regardless of the degree of collapse, and that the same amount of cement was injected into the created space. Furthermore, the results suggested that the focal alignment changes were more important than the stiffness of the vertebrae for predicting the risk of EO-AVFs.

These findings raised new questions about how to reduce the incidence of EO-AVFs. Patients in our study were treated during the subacute phase after the onset of symptoms, and we found that the local kyphosis angle was a greater risk for EO-AVFs than was stiffness of the cemented vertebrae. Therefore, early intervention for older patients may reduce EO-AVFs before progression of vertebral collapse. Confirming whether the EO-AVF rate is lower for BKP before collapse of the VB requires further comparative studies of the incidence of EO-AVFs for patients who have undergone early intervention and for those with later intervention after conservative treatment.

Advantages of the current study were that the patient backgrounds were homogenous, as were the treatment courses for vertebral fractures. Surgery for patients who did and did not develop EO-AVFs had similar timing because sustained painful vertebral fractures following the initial conservative treatment are good indications for kyphoplasty. Almost all patients had been treated with nonsteroidal anti-inflammatory drugs and/or a brace at a primary hospital, and the severity of vertebral fractures was similar regarding resistance to conservative therapy. Comorbidities and the use of osteoporotic drugs were also similar in the 2 groups. These similar background factors may have decreased the effects of confounders.

There were several limitations to this study. First, this study was retrospective, which can lead to selection bias regarding patients and risk factor variables. Second, relatively few patients were treated with kyphoplasty for thoracic and lumbar lesions, and the loading burden on the vertebrae differed among thoracolumbar and lumbar lesions. This may have influenced the overall incidence of EO-AVFs and the significance of risk factors. To clarify the effects of the spinal level, it is necessary to investigate risk factors for EO-AVFs at each location. Third, age-related confounding factors, such as spinal global malalignment, could not be completely excluded. Sagittal balance inclines forward with age in osteoporotic patients and in persons with normal bone strength because of muscle weakness and degenerative spinal deformity.[35] An increase in the sagittal vertical axis is also a risk factor for AVF following PV.[36] However, a multivariate analysis showed that preoperative VA was a risk factor for EO-AVFs, independent of age. These limitations require further evaluation using a prospective study.

Conclusion

Our results showed that age, preoperative VA, and corrected VA are risk factors for EO-AVFs following BKP. The 2 types of VA were strongly correlated because of the reduction ability of BKP. Acute mechanical environmental changes may be involved in the pathology of EO-AVFs, and a higher EO-AVF rate occurred for thoracolumbar lesions than for lumbar lesions. Surgeons should carefully consider preoperative and postoperative treatments for osteoporotic patients who have undergone kyphoplasty.

Declaration of Conflicting Interests

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Informed Consent

Informed consent was obtained from all individual participants included in the study.

Ethical Approval

All procedures performed during studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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