Endplate Deficits and Posterior Wall Injury Are Predictive of Prolonged Back Pain after Osteoporotic Vertebral Body Fracture

Masatoshi Teraguchi[1)], Mamoru Kawakami[2)], Yoshio Enyo[1)], Ryohei Kagotani[1)], Yoshimasa Mera[1)], Keita Kitayama[1)], Hiroyuki Oka[3)], Yoshio Yamamoto[1)], Masafumi Nakagawa[1)], Tomohiro Nakatani[1)] and Yukihiro Nakagawa[1)]

1) Spine Care Center, Wakayama Medical University Kihoku Hospital, Wakayama, Japan
2) Department of Orthopaedic Surgery, Saiseikai Wakayama Hospital, Wakayama, Japan
3) Department of Medical Research and Management for Musculoskeletal Pain, 22nd Century Medical and Research Center, Faculty of Medicine, The University of Tokyo, Tokyo, Japan

Abstract:

Introduction: Osteoporotic vertebral compression fracture (OVCF) in the elderly is a major public health concern. This retrospective case-control study aimed to determine the difference in interobserver reliability between radiography, magnetic resonance imaging (MRI), and computed tomography (CT), respectively, and whether CT radiological findings can predict prolonged back pain at 2 weeks after OVCFs.

Methods: Patients were divided into the prolonged back pain group or the recovered back pain group depending on the numerical rating scale at 2 weeks after admission. Radiography, MRI, and CT images were classified on the basis of conventions described by previous classifications. Interobserver reliability was calculated on images rated by two board-certified spine surgeons. Multivariate logistic regression models were used to evaluate whether the presence or absence of anterior wall injury, endplate deficit, posterior wall injury, lateral wall injury, or intervertebral disc deficit on CT was predictive of prolonged back pain.

Results: Of the 130 patients, 89 cases (68.5%) involved prolonged back pain at 2 weeks after admission. Neither average age (79.8 vs. 80.1 years, respectively) nor duration to initial consultation (9.4 vs. 6.4 days, respectively) differed significantly between the prolonged and recovered back pain groups. Interobserver reliability was 0.51, 0.77 (0.67-0.86), and 0.82 (0.72-0.92) for radiography, MRI, and CT, respectively.

After adjusting for confounding factors such as age, sex, duration to initial consultation, and extent of OVCF, the multivariate analysis showed that the presence of endplate deficit and posterior wall injury was a significant predictive factor for prolonged back pain (odds ratio [OR] 8.5, area under the curve (AUC); 0.79 and OR 2.5, AUC 0.72), respectively.

Conclusions: Good reliability assessments of CT-based evaluations were noted. After a detailed novel CT evaluation at initial presentation, the presence of an endplate deficit and posterior wall injury was the significant risk factor for prolonged back pain at 2 weeks after an OVCF.

Keywords:

Interobserver reliability, prolonged back pain, endplate deficit, posterior wall injury, balloon kyphoplasty, computed tomography, CT

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Introduction

Osteoporotic vertebral compression fractures (OVCF) represent a significant medical and socioeconomic burden, with an estimated 1.4 million new OVCFs every year globally[1)]. The long-term consequences of OVCFs include chronic back pain, decreased physical function and quality of life, and depression[2-7)]. The most common treatment strategies for OVCFs are balloon kyphoplasty (BKP), vertebroplasty, and conservative treatments.

The use of cement augmentation, such as BKP, versus conservative management in the treatment of OVCFs is a

Corresponding author: Masatoshi Teraguchi, m-tera@wakayama-med.ac.jp
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debatable topic[5,7-11]. In most OVCFs, the associated pain gradually subsides with conservative treatment as the fracture's union and stability improve[8]. However, approximately 80% of patients with delayed union have moderate or severe back pain; furthermore, the delayed union of the vertebra may lead to delayed-onset collapse and the development of neurological symptoms[12,13]. The need for BKP, vertebroplasty, or spinal fusion surgery in cases of delayed union can be quantified using a special tool, which has been helpful for the recovery of painful OVCFs[5,9-11].

For patients with acute OVCFs, BKP and vertebroplasty are performed to reduce pain and preserve vertebral height[5,9-11,13,14]. Although early surgical intervention is effective, there are some potential limitations including the risk of extravasation of the cement, subsequent OVCFs, systemic cardiopulmonary side effects, and the associated cost of the procedure[11,14,15]. Moreover, because bone cement has no osteoconductive or inductive properties, the high polymerization temperatures can damage the surrounding tissue. Consequently, surgery should be limited to when conservative treatment is not indicated, the risk to the patient is carefully weighted, and the surgeon is experienced in the procedure[11,14,15].

The characteristics of OVCFs differ markedly along the disease course, with increasing sagittal deformity associated with the development of chronic pain over time. However, only a few studies have paid attention to the timing for BKP[16,17]. Phillips et al. reported that early surgery yielded a good degree of correction to local spinal kyphosis[16]. Minamide et al. also reported that early intervention resulted in better alignment, better back pain scores, and a reduced rate of subsequent vertebral fracture[17]. Furthermore, Nieuwenhuijse et al. found an immediate and sustainable improvement of back pain and health-related quality of life after vertebral cement augmentation, independent of time since fracture[18]. These reports suggest that early timing is important for successful intervention.

A previous study from our group has shown the efficacy of stay-active therapy for acute OVCFs. However, patients with a moderate-to-high pain score (numerical rating scale (NRS)≥4) at 2 weeks after hospitalization had prolonged back pain after discharge[19], highlighting the need to understand the risk factors for prolonged back pain after acute OVCFs. Sugita et al. reported that radiography imaging-based classification could predict pseudoarthrosis and delayed-onset collapse[20]; however, a limitation of this study is the use of only the sagittal view, which may have affected prediction reliability. Other reports found that a diffuse low-intensity- or a high-intensity signal change on T2-weighted MRI was associated with an increased risk of delayed union[21,22]. A major limitation in one study, which the authors mentioned, was that the patient was in the supine position for a prolonged time before the MRI, and this has been shown to influence the signal change[22]. The present study aimed to determine the difference in interobserver reliability between the radiography, MRI, and CT and to investigate whether early CT can be used to predict a prolonged back pain to determine the timing of intervention with BKP for OVCFs.

Materials and Methods

Patients

In total, 130 consecutive patients with symptomatic OVCFs participated in this prospective study, conducted from September 2016 to February 2020. After their OVCFs diagnosis was confirmed, patients were placed in a lumbosacral corset and hospitalized as soon as possible. This research has been approved by the Institutional Review Board of the authors. The inclusion criteria were age >65 years, MRI-confirmed diagnosis of a recent OVCF, and the onset of back pain within 4 weeks before the first consultation at our hospital. The exclusion criteria were pathological fractures, more than one recent fracture, malignant disease, dementia, and high-energy injuries. OVCFs were considered recent if the interval between the onset of symptoms and the first consultation was within 4 weeks, and the MRI showed an abnormal signal change in the vertebral body.

Time of injury was judged retrospectively by questioning the patient and their family. The severity of pain was assessed by patients' self-report using NRS score (0-10) on the average level of back pain that the patient had experienced in the preceding week. Pain severity was assessed at the first consultation after injury and the 2 week follow-up after hospitalization. Patients with NRS≥4 were classified as having prolonged back pain, and patients with NRS<4 were classified as having recovered from back pain, according to previously published data by us showing that patients with a moderate-to-high pain score (NRS≥4) at 2 weeks after hospitalization had prolonged back pain at discharge[19].

Imaging assessment

At the first consultation, the patients were examined using plain radiography, CT, and MRI of the spine. A lateral view on plain radiography was classified as previously described by Sugita, projecting type, swelled front type, bow-shaped type, and dented type[20]. The patterns of signal changes within the fractured vertebral bodies on MRI were classified on the basis of midsagittal T1-weighted images (T1WI) and T2-weighted images (T2WI). The signal intensity changes on T1WI were classified into three patterns: diffuse low-, confined low-, and no-signal change. The signal intensity changes on T2WI were classified into four patterns: confined low, diffuse low, confined high, and diffuse high change.

Sagittal, coronal, and axial images of the spine, including the fractured vertebrae, were obtained using CT and evaluated for OVCF. OVCF classification was performed depending on previous reports and comprised the projecting type, swelled front type, and dented type at the anterior wall[20]. Additionally, "endplate deficit" was defined as either end-

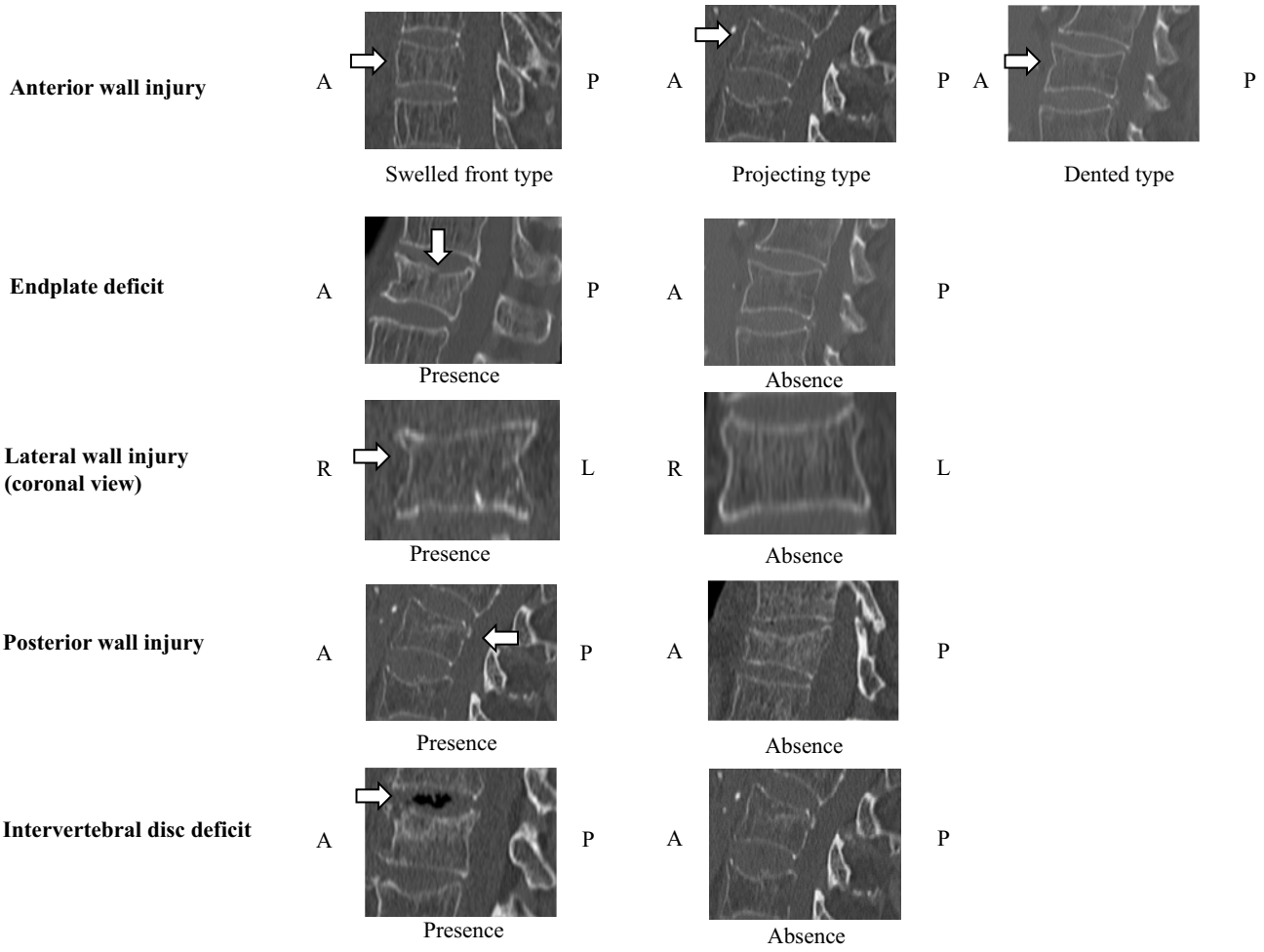

Figure 1. Osteoporotic vertebral fracture classification based on computed tomography.
A; anterior, P; posterior, R; right, L; left

plate failure in the vertebral endplate, and "intervertebral disc deficit" was defined as intervertebral disc vacuum failure. Fig. 1 shows the presence or absence of endplate deficit; posterior wall injury, lateral wall injury, and intervertebral disc deficit were also noted.

Each image was evaluated by two board-certified spine surgeons (MT and YE) who were blinded to the patient's information, and the measures of interobserver reliability were calculated. Two separate sets of 30 randomly selected patients were scored by evaluators (MT and YE) for interobserver reliability. A kappa value of >0.90 was considered excellent and that between 0.80 and 0.90 was considered good[23,24]. Any disagreements in the classification of CT were settled by consensus after reliability assessments were completed.

Statistical analyses

All statistical analyses were performed using JMP, version 14 (SAS Institute Japan, Tokyo, Japan). Descriptive statistics were calculated for all variables, and between-group comparisons were tested using two-sample t-tests (age and duration to the initial consultation), and Fisher's exact tests (sex and extent of OVCFs). Data are presented as means±standard deviations. A comparison of CT-based evaluation between the prolonged back pain group and the recovered back pain group was performed using Mann-Whitney U tests.

Multivariate logistic regression models were used to evaluate the association between each radiographical factor and prolonged back pain after adjustment for age, sex, duration to initial consultation, and extent of OVCFs. The receiver operating characteristic curve with sensitivity and specificity was constructed to determine the efficacy of CT findings for prolonged back pain. The threshold for statistical significance was set at a p-value of <0.05, and the corresponding 95% CIs were assessed.

Results

Of the 130 patients in total, 89 (68.5%) had prolonged back pain (pain score of ≥4) at 2 weeks after the initial consultation. As summarized in Table 1, the average age was not significantly different between the prolonged and the recovered back pain groups (79.8 vs. 80.1 years, respectively), and the duration to initial consultation was also not significantly different (9.4 vs. 6.4 days, respectively) (p=0.07). The distribution of the fractures was significantly different between the two groups, with thoracic and thoracolumbar

Table 1. Case Characteristics.

	Prolonged back pain (NRS≥4)	Recovered back pain (NRS<4)	p value
Cases (male/female)	89 (25/64)	41 (10/31)	p=0.66
Age (SD) (years)	79.8 (7.9)	80.1 (11.1)	p=0.87
Duration of first consultation after the onset of back pain (SD) (days)	9.4 (8.7)	6.4 (8.0)	p=0.07
Level of fracture			
Thoracic (T8–T11)	8	0	
Thoracolumbar junction (T12–L2)	69	28	p<0.05
Lumbar (L3–L5)	12	13	

SD: standard deviation, NRS: numeric rating scale

Table 2. Comparison of Injury Types between the Prolonged Back Pain Group and the Recovered Back Pain Group.

	Cases	Prolonged back pain (NRS≥4)	Recovered back pain (NRS<4)	p value
Anterior wall injury (swelled front type)	15	9 (60.0%)	6 (40.0%)	p=0.45
Anterior wall injury (projecting type)	55	36 (65.5%)	19 (34.5%)	p=0.53
Anterior wall injury (dented type)	60	44 (73.3%)	16 (26.7%)	p=0.27
Endplate deficit	93	76 (81.7%)	17 (18.3%)	p<0.0001
Posterior wall injury	61	38 (62.3%)	23 (37.7%)	p=0.15
Lateral wall injury	91	66 (72.5%)	25 (27.5%)	p=0.13
Intervertebral disc deficit	46	37 (80.4%)	9 (19.6%)	p<0.05

junction fractures being more common within the prolonged back pain group.

Interobserver reliability value was 0.51 for radiography evaluation. The value was 0.86 for T1WI and 0.67 for T2WI on MRI, respectively. Finally, the value was 0.74 for anterior wall injury, 0.87 for endplate deficit, 0.72 for posterior wall injury, 0.92 for lateral wall injury, and 0.83 for intervertebral disc deficit on CT, respectively.

Table 2 summarizes the ratio differences in CT classification between the prolonged and recovered back pain groups. The proportion of patients with endplate deficit and intervertebral disc deficit was significantly different between the two groups (81.7% vs. 18.3%, and 80.4% vs. 19.6%, respectively) ($p<0.0001$ and $p<0.05$).

After adjusting for confounding factors in the multivariate analysis, the presence of an endplate deficit and posterior wall injury was the significant predictive factor for prolonged back pain (odds ratio (OR) 8.52/area under the curve (AUC); 0.79 and OR 2.54/AUC 0.72), as shown in Table 3.

Discussion

In this study, we observed that good reliability assessments of CT-based evaluations were noted and that posterior wall injury and endplate deficit visible on CT images at the first hospital consultation was significantly associated with prolonged back pain at 2 weeks after an OVCF injury, respectively.

Several reports describe excellent early relief pain by BKP[16-18,25,26], suggesting that BKP and other surgical interventions can contribute to post-OVCF recovery and better quality of life in elderly patients. However, even if surgical interventions have a considerable benefit, the timing of such interventions must be optimized. We would suggest that BKP is indicated only in those patients with painful OVCFs in the acute phase on some imaging. Sugita et al. demonstrated that swelled-front-type, bow-shaped-type, and projecting-type fractures on radiography were associated with a poor prognosis with late collapse and often showed a vacuum cleft[20]; however, they did not measure interobserver reliability. Although Takahashi et al. concluded that interobserver reliability in MRI for T1WI and T2WI of 30 randomly chosen vertebral bodies was excellent[22], the authors mentioned that the timing of the MRI examination can influence the signal change; thus, CT may be a better tool to investigate prolonged back pain in OVCF patients.

There is currently no universal classification system for OVCFs. The commonly used trauma classifications such as the AO spine[27] and the Denis classification[28] were not initially developed for osteoporotic fractures. A new classification, based on the work of the Spine Section of the German Society for Orthopaedics and Trauma, proposes five subgroups of osteoporotic fractures with substantial interobserver reliability[29]. This study shows a high reliability between two observers for CT classification; thus, it may be useful in predicting prolonged back pain.

Few reports have focused on the impact of timing on the differences in surgical outcomes for OVCFs[16-18,25,26]. Mina-

Table 3. Predictive Values and Odds Ratios of Each Radiographic Finding for Prolonged Back Pain.

	SEN	SPE	AUC	Odds ratio	95% CI	p value
Anterior wall injury (swelled front type)	62.9	78.1	0.7	1.07	0.3–3.4	0.9
Anterior wall injury (dented type)	76.4	60.9	0.71	1.62	0.7–3.7	0.25
Anterior wall injury (projecting type)	83.2	56.1	0.71	1.55	0.7–3.5	0.29
Endplate deficit	78.7	73.2	0.79	8.52	3.3–22.2	<0.0001
Posterior wall injury	76.4	60.9	0.72	2.54	1.1–6.0	0.03
Lateral wall injury	55	85.4	0.71	1.82	0.8–4.2	0.16
Intervertebral disc deficit	83.2	58.5	0.73	2.32	0.9–5.9	0.08

SEN: sensitivity, SPE: specificity, AUC: area under the curve, CI: confidence interval

The odds ratios were adjusted for age, sex, duration to initial consultation, and extent of osteoporotic vertebral compression fracture.

mide et al. reported that early BKP resulted in better long-term alignment and lower subsequent fracture rates than a delayed procedure[17]. Kaufmann et al. suggested that vertebroplasty for OVCF is highly efficacious for pain relief and improvement of patient mobility regardless of fracture age[25]. These authors reported no apparent impact of surgery timing on differences in the outcome of vertebroplasty, although the effect may be slightly blunted in patients requiring narcotics before the procedure and in those who have older fractures. It is important to note that this study did not assess radiological factors. In the current study, posterior wall injury and endplate deficits on CT images were observed at the first hospital consultation in most patients belonging to the prolonged back pain group, suggesting that the destruction of the vertebral body may be severe in patients with a long-term vertebral cleft.

Watts et al.[14] also reported that vertebral posterior wall injury and endplate deficit showed high specificity for predicting vertebral clefts at the 6 month follow-up. They speculated the breakage extended to the endplate, and thus, the applied magnitude could be high and complicated for the osteoporotic vertebrae. Thus, the vertebral damage was sometimes extensive. Additionally, Sugita et al.[20] reported that bow-shaped-type fractures with an endplate deficit on radiography had a poor prognosis and often resulted in late collapse and showed a vacuum cleft. OVCFs were influenced by not only the vertebral fracture but also the endplate and disc degeneration of the complex unit required for the spinal integrity of the anterior spinal column[30,31].

Nakamae et al.[30] reported that posterior wall injury with vertebral instability was significantly associated with painful OVCFs. This suggests that OVCFs are influenced by the vertebral fracture itself and by the endplate and disc degeneration of the adjacent spinal column[20,30,31]. Posterior wall injury represents not only the breakage of the anterior column but also the damage of the middle column due to the weakness of the osteoporotic vertebral body and easy collapse according to the three-column theory reported by Sugita et al.[20].

The limitations in the present study should also be considered: First, we assessed patients only within a short period. Therefore, it remains unclear whether the differences between the prolonged and recovered back pain groups will remain over the long term. Second, we evaluated the CT image at the first consultation. The average time from the onset of back pain to the initial consultation was 8.5 days in this study. The length of the delay in consultation may affect the indication for intervention. Therefore, future studies should investigate the effects of early diagnosis of OVCFs and early treatment using BKP.

In conclusion, we demonstrated good reliability assessments of CT-based evaluations and that radiological factors on CT images acquired at first evaluation are predictive of prolonged back pain after OVCFs. Following detailed CT classification, the presence of posterior wall injury and endplate deficit was significantly associated with prolonged back pain 2 weeks after hospitalization.

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Informed Consent: Informed consent was obtained by all participants in this study.

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