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The Value of Dynamic Radiographs in Diagnosing the Painful Vertebrae in Osteoporotic Compression Fractures

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Background and Purpose: Many authors have reported the increase in vertebral body height after vertebroplasty; if the fractured vertebrae are mobile, we must be able to demonstrate its mobility in radiographs. The purpose of this study was to find out the diagnostic value of dynamic radiographs and the percentage of mobile vertebrae in painful VCFs.

Materials and Methods: From September 2005 to September 2008, 105 patients underwent surgery to treat 144 painful osteoporotic vertebral compression fractures (VCFs). The indications for surgery were severe pain and MRI confirmed active edematous lesions. Preoperative sitting lateral radiographs of the fractured vertebrae were compared with supine cross-table (with bolster beneath) lateral radiographs to determine the presence or absence of dynamic mobility. Kyphotic angle and anterior vertebral body height were measured.

Results: The patients' age ranged from 62 to 90 years. There were 19 men and 86 women. The total number of mobile VCFs was 126 (87.5%). One hundred and four (99%) patients had at least one mobile VCF. The average anterior vertebral height in sitting lateral radiographs was 13.53 ± 6.80 mm, and increased to 22.01 ± 6.13 mm in supine cross-table with bolster lateral radiographs. The average vertebral body height increase was 8.48 ± 5.36 mm.

Conclusions: Dynamic (sitting and supine with bolster) radiographs can be valuable

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in diagnosing the painful vertebrae in painful VCFs; the sensitivity is 0.88 in this study.

Key words: osteoporosis, vertebral compression fractures, sitting and supine radiographs, dynamic mobility, diagnosis

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Introduction

McKiernan and colleagues[1] demonstrated dynamic mobility in 44% of 41 patients who underwent vertebroplasty. Many authors have also reported the increase in vertebral body height after vertebroplasty.[2, 3] Chin et al.[4] reported that postural reduction vertebroplasty can lead to significant restoration of vertebral body height and correction of kyphosis in osteoporotic vertebral compression fractures (VCFs). Lee et al.[5] showed the same results by closed reduction vertebroplasty. Orler et al.[6] used lordoplasty to restore the lordosis. If the vertebral body height can be increased by postural reduction or closed reduction during vertebroplasty, it must be mobile (non-union). If it is mobile, we must be able to demonstrate its mobility in radiographs.

X-ray and magnetic resonance imaging (MRI) are the primary imaging modalities for evaluating suspected VCFs. However, X-ray sometimes can't differentiate recent or unhealed fractures from those that have healed. Only MRI and bone scan can be used to evaluate the edematous (symptomatic) lesion and determine which vertebra is symptomatic and requires treatment. If painful VCFs can be demonstrated to be mobile in dynamic radiographs, then we can use dynamic radiographs to diagnose the painful VCFs. The object of this study is to evaluate the percentage of mobile vertebrae in MRI-proved painful osteoporotic VCFs with modified dynamic

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radiographs and to see whether this technique is useful in diagnosing the painful VCFs.

Materials and Methods

The Institutional Review Board approved this radiographic analysis of 105 consecutive patients with 144 VCFs that underwent vertebroplasty (86 patients) or open surgery (19 patients) in our institute. The indications for treatment (vertebroplasty or surgery) were severe pain that was not responsive to medical treatment, and MRI confirmed active edematous lesions (hyper-intensity-signal on short-tau inversion recovery (STIR) sequence and/or contrast enhancement on fat-suppressed gadolinium-enhanced T1-weighted imaging). Pre-procedural anterior-posterior (AP) and lateral radiographs were taken. In addition, each patient had pre-procedural sitting lateral radiograph centered on the fractured vertebra, and a supine cross-table lateral radiograph centered on the index vertebra with a bolster (10 cm in height) placed beneath it.[1] As outcome measurement, a visual analog scale (VAS) with 10 divisions was used.

Digital files of the patients' radiographs were retrieved from the picture archiving and communication system (PACS) for analysis. Two of the authors (D-F L. and Y- J C.) performed these measurements. Intra-observer and inter-observer reproducibility of these measurements was evaluated by using intra-class correlation coefficients. The

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kyphotic angles of the vertebral compression fractures were measured from the superior and inferior endplate of the fractured (compressed) vertebra. The change of kyphotic angle was calculated as the sitting angle minus the supine (with bolster) angle. From the lateral projection, 6 points were hand selected and marked on each fractured vertebra (index vertebra) and the nearest non-fractured vertebra (referent vertebra), based on the techniques used by McKiernan.[7] The anterior vertebral body height of fractured vertebra was measured. In order to remove the inter-radiographic magnification error, we match each index VCF to the referent vertebra on the sitting lateral radiograph. Each index-referent vertebral pair remained constant throughout the analysis. In supine cross-table with bolster lateral radiographs, dimensions of the index vertebra were expressed as percentage of the analogous dimension of the referent vertebra, and then scaled to the absolute dimensions of the original sitting lateral radiograph. This cancels out any residual inter-radiographic magnification error and allows for direct radiographic comparisons. According to the height change, we defined the vertebra as non-mobile (height change ≦ 2 mm), mild mobile (between 2 mm and 6 mm) and mobile (> 6 mm).

Statistical Analysis

The results were expressed as the mean ± the standard deviation (SD). The statistical significance of changes in vertebral body height and kyphotic angle was

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evaluated with the paired *t* test in which a *P* value < 0.05 was considered to indicate a statistically significant difference. All statistical analyses were carried out using the statistical package SPSS 12.0 (SPSS Inc., Chicago, IL, USA), Windows version.

Results

One hundred and five patients underwent vertebroplasty or surgical procedures to treat 144 MRI-proved edematous VCFs. The patients' age ranged from 62 to 90 years (mean, 76 years). There were 19 men and 86 women. Seventy-one patients (67.6%) had 1-level fracture, 30 patients had 2-level fractures, and 4 patients had 3-level fractures. L1 was the most common level affected in 37 patients, followed by T12 in 30 patients, L2 and L3 in 17 patients.

Pain assessed by the VAS significantly (*P* <0.001) decreased from a mean of 8.9 ± 0.7 (range, 7 to 10) before procedure to 1.8 ± 1.5 (range, 0 to 9) after 1 month follow-up. Ninety-eight patients (93%) satisfied with the results. Only one patient described no improvement in pain after vertebroplasty.

Intra-observer (Y-J C.) reproducibility was 0.95 for height of the vertebral body and 0.96 for kyphotic angle. Inter-observer reproducibility was 0.94 for heights and 0.97 for kyphotic angle. The average kyphotic angle in sitting lateral radiographs was 18.18 ± 8.22 degrees (mean ± SD), (range, 0 to 36 degrees), and changed to 7.52 ± 7.25 degrees (range, -15 to 26 degrees) in supine cross-table with bolster radiographs.

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The average difference between sitting and supine with bolster was 10.67 ± 6.67 degrees (range, -2 to 27 degrees), which was statistically significant ($P < 0.001$). The average anterior vertebral height in sitting lateral radiographs was 13.53 ± 6.80 mm (range, 0.98 to 29.48 mm), and increased to 22.01 ± 6.13 mm (range, 6.09 to 38.53 mm) in supine cross table with bolster lateral radiographs. The average vertebral body height increase was 8.48 ± 5.36 mm (range, -1.17 to 24.04 mm), which was statistically significant ($P < 0.001$).

Of these 144 MRI-proved edematous fractured vertebrae, 126 (87.5%) were mobile and 18 (12.5%) were non-mobile. However, in all 105 treated patients, 104 (99%) had at least one mobile VCF; only 1 patient had single-level non-mobile compression fracture at L5. Seventeen patients had both mobile and non-mobile VCFs. In the patients with 1-level VCF, 98.6% (70/71) had a mobile VCF. In the patients with 2- or 3-level VCFs, 100% (34/34) of them had at least one mobile VCF.

Discussion

Toyone et al.[8] used supine and standing radiographs, and McKiernan[1] used standing and supine (with or without bolster) radiographs to demonstrate the mobility. In McKiernan's study,[1] dynamic fracture mobility was demonstrated only in 44% of patients, but they didn't use a bolster in supine lateral radiographs in all patients. The vertebral body height is taller in supine with bolster radiographs (Fig 1B, white arrow)

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than in supine only (Fig 1C, white arrow). In McKiernan's study, 23 mobile fractures all showed marked mobility and the average anterior vertebral height increased 106% as compared with initial fracture height.[1] No case of mild mobility was noted in their study. However, in another study by McKiernan,[9] they demonstrated latent mobility of osteoporotic VCFs that was not obvious in their current standing and supine lateral radiographs. This means that mild mobility cannot be demonstrated in standing and supine lateral radiographs. In order to get the best comparison effect, we modified this technique and used sitting (instead of standing) and supine cross-table with bolster lateral radiographs in every patient. Although 99% of our patients showed dynamic mobility, 24 patients showed only mild mobility (Fig 2, white arrow). The mild mobility in these patients may be not obvious in standing and supine radiographs. If the patients with mild mobile VCFs are excluded, then the percentage drops to 76.2%.

In this study, 87.5% of 144 MRI-proven edematous VCFs were demonstrated to be mobile. The sensitivity of dynamic radiographs in diagnosing the MRI-proved edematous VCFs is 0.87. However, in patients with painful VCFs that need vertebroplasty or surgical intervention, 99% of patients can be demonstrated to have at least one mobile VCF. The sensitivity of dynamic radiographs in diagnosing the painful vertebrae in patients with severe pain is 0.99. An explanation is that not all edematous vertebrae are mobile; however, in patients with severe back pain that need

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vertebroplasty or surgical treatment, there always has at least one mobile vertebra. Toyone et al.[8] demonstrated a significant correlation between back pain and changes in wedging rate from supine to standing position. Changes in wedging rate more than 10% were always associated with more severe back pain. If the vertebrae are edematous but not mobile, the pain severity should be lower. So in a patient with mobile and non-mobile MRI-proven edematous VCFs, the mobile VCF should be the major pain source. In this study, one patient had a 3-level compression fractures; 1 mobile and 2 non-mobile. We only treated 2 vertebrae (1 mobile and 1 non-mobile), and he still received dramatic pain improvement (Fig 3).

Since MRI can provide an accurate diagnosis, what is the role of dynamic radiographs? In the time that elapses between the initial MRI evaluation and vertebroplasty, it is possible for additional fractures to occur. Benz et al.[10] recommended a repeat pre-procedure MRI obtained within 1 week in select candidates to help ensure that all painful fractures are treated. However, the disadvantages of pre-procedure MRI include the time, expense, and demands on the radiology department. Since dynamic radiographs are sensitive in diagnosing the painful vertebrae, they can be used as a pre-procedure re-evaluation examination to rule out any new lesions if the MRI was not recently preformed. The dynamic radiographs will be more valuable in patients who cannot undergo MRI examination.

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In addition to its diagnostic value, it can help interventionalists estimate the post-procedure vertebra height and shape, and cement injection area and amount. It can also help interventionalists assess the feasibility of vertebroplasty in vertebral plana (Fig 1, black arrow).

Although the dynamic radiographs are valuable in diagnosing the painful vertebrae in VCFs, they cannot replace MRI. MRI not only can accurately diagnose the painful VCFs, but most importantly can differentiate simple compression from pathological fracture. MRI is still recommended in every patient who will undergo vertebroplasty or surgical intervention.

Conclusion

A modified radiographic technique (sitting and supine with bolster lateral radiographs) can be valuable in diagnosing the painful vertebrae in osteoporotic VCFs. The sensitivity is 0.88 in this study. Based on our results, we suggest using dynamic sitting and supine with bolster lateral radiographs as a screening examination or pre-procedural examination if the MRI was not recently preformed.

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Figure Legends

FIGURE 1. A 69 year-old woman suffered from severe back pain due to T9 and L1 compression fracture. Sitting (A) and supine with bolster (B) lateral radiographs show mobility at T9 (white arrow) and L1 (black arrow). C, Sagittal STIR MR image demonstrates hyper-intensity at T9, but hypo-intensity at L1. D, Post-vertebroplasty lateral radiograph shows cement filling inT9 and L1

FIGURE2. A 65 year-old woman suffered from severe back pain due to T8 and T10 compression fracture. Sitting (A) and supine with bolster (B) lateral radiographs show mild mobility at T8 (white arrow) and no mobility at T10 (black arrow). C, Sagittal STIR MR image demonstrates hyper-intensity at T8 and T10. D, Post-vertebroplasty lateral radiograph shows cement filling inT8 and T10.

FIGURE 3. A 74 year-old man suffered from severe back pain due to T6, T10 and L1 compression fracture. Sitting (A) and supine with bolster (B) lateral radiographs show mobility at L1 (black arrow) but no mobility at T6 (hallow arrow) and T10 (white arrow). C, Contrast-enhanced T1-weighted MR image demonstrates contrast-enhancement at T6, T10 and L1. D, Post-vertebroplasty lateral radiograph shows cement filling inT10 and L1. Vertebroplasty was not performed at T6, but he still received dramatic improvement.

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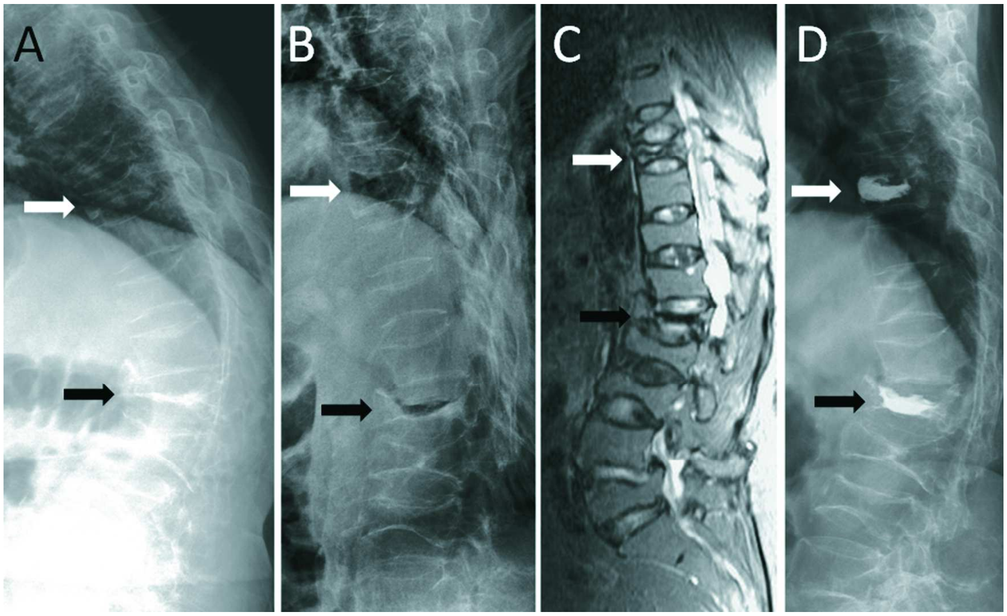

A 69 year-old woman suffered from severe back pain due to T9 and L1 compression fracture. Sitting (A) and supine with bolster (B) lateral radiographs show mobility at T9 (white arrow) and L1 (black arrow). C, Sagittal STIR MR image demonstrates hyper-intensity at T9, but hypo-intensity at L1. D, Post-vertebroplasty lateral radiograph shows cement filling inT9 and L1.
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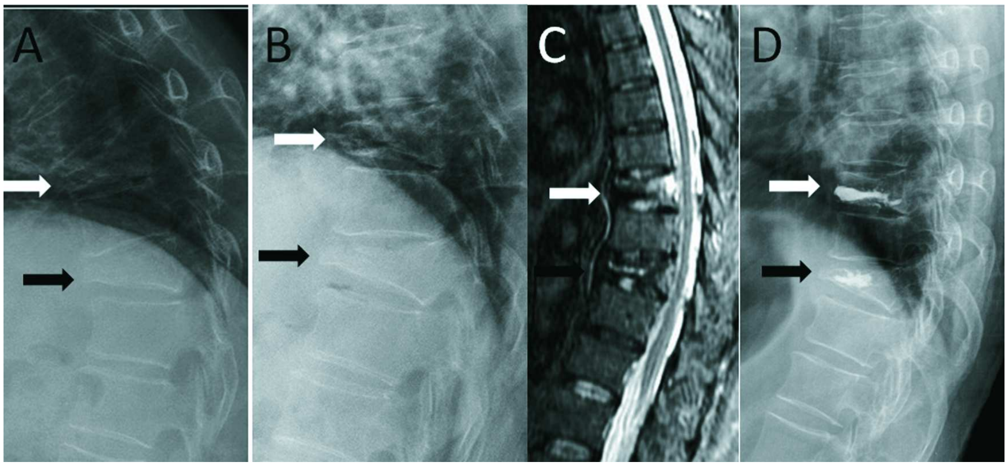

A 65 year-old woman suffered from severe back pain due to T8 and T10 compression fracture. Sitting (A) and supine with bolster (B) lateral radiographs show mild mobility at T8 (white arrow) and no mobility at T10 (black arrow). C, Sagittal STIR MR image demonstrates hyper-intensity at T8 and T10. D, Post-vertebroplasty lateral radiograph shows cement filling inT8 and T10.
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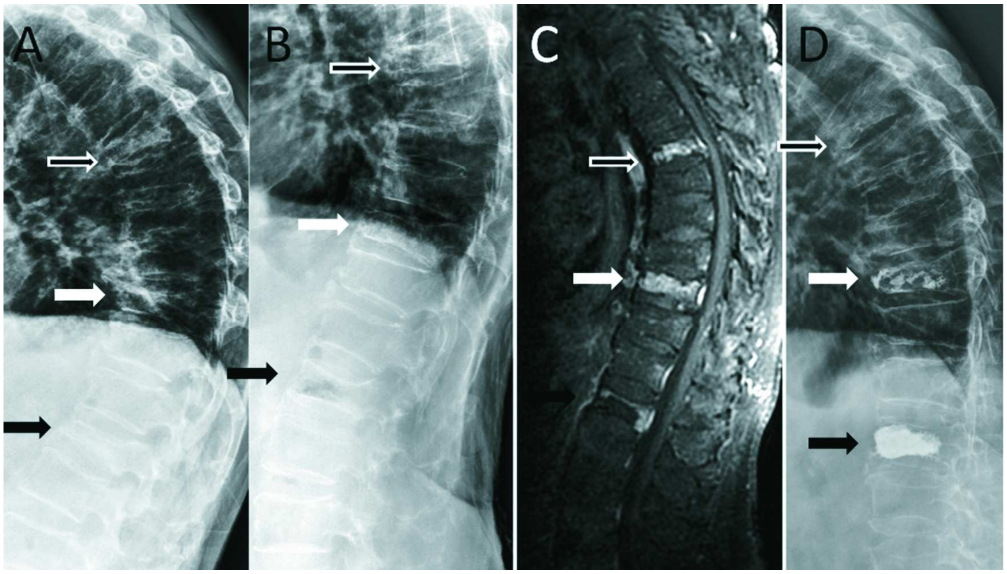

A 74 year-old man suffered from severe back pain due to T6, T10 and L1 compression fracture. Sitting (A) and supine with bolster (B) lateral radiographs show mobility at L1 (black arrow) but no mobility at T6 (hallow arrow) and T10 (white arrow). C, Contrast-enhanced T1-weighted MR image demonstrates contrast-enhancement at T6, T10 and L1. D, Post-vertebroplasty lateral radiograph shows cement filling inT10 and L1. Vertebroplasty was not performed at T6, but he still received dramatic improvement.
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