Sandwich Vertebral Fracture in the Study of Adjacent-level Fracture After Vertebral Cement Augmentation

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**abstract**

The literature is inconclusive on the development of adjacent-level vertebral fracture after initial cement augmentation. A preliminary hypothesis is that cement injection exaggerates force transmission to the adjacent vertebral bodies, thereby predisposing those levels to future fractures. A sandwich vertebra is an intact vertebral body located between 2 previously cemented vertebrae. The purpose of this study was to determine whether the risk of adjacent-level fracture increased due to load shift after a cement injection procedure. The authors retrospectively investigated the rate of adjacent-level fracture after sandwiching compared with conservative treatment and determined the potential causative factors of sandwich vertebral fracture. Age, sex, weight, height, body mass index, follow-up period, and location of sandwich level (T10-L2 or nonT10-L2 junction) were assessed. Surgical variables, including surgical procedure (vertebroplasty or balloon kyphoplasty), surgical approach (through uni- or bilateral pedicle), volume of cement injected into the painful vertebrae, cement leakage into the intervertebral disk, cumulative number of treated levels, and pre- and postoperative kyphotic angulation of the sandwich region, were also analyzed. Nine of 42 sandwiched levels developed fatigue fractures, whereas 11 of 71 patients treated with conservative therapy sustained new vertebral fractures adjacent to the treated levels. Only preoperative kyphotic angulation was the variable positively associated with sandwich vertebral fracture at follow-up (P = .021). Although subjected to double load shifts, the sandwich vertebra was not prone to structural failure. Thus, cement augmentation protocol does not increase the incidence of adjacent vertebral fracture.

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Percutaneous vertebroplasty and balloon kyphoplasty are radiological, percutaneous puncture procedures, entailing bone cement injection into a destroyed vertebral body with the aim of pain relief and bone reinforcement. Due to its minimal invasion and immediate pain relief, percutaneous vertebroplasty/balloon kyphoplasty is steadily gaining popularity in the treatment of painful tumor infiltration diseases, such as aggressive hemangioma, metastatic carcinoma, or multiple myeloma, and for patients who have intractable pain due to osteoporotic thoracolumbar fractures.

It is generally accepted that cement injection strengthens vertebrae to withstand a higher axial compressive force prior to fracture and to stiffen the cemented vertebrae beyond its initial stiffness. However, whether vertebral cement augmentation increases the risk of adjacent vertebral fracture and what the mechanism is of new fracture at adjacent levels remains highly controversial. Baroud et al. and Poliak et al. reported that filling vertebrae with bone cement may substantially alter the stiffness and induce a load shift across the intervertebral disk and that the resultant increased inward bulge of the endplate adjacent to the augmented one may increase the risk of adjacent fractures. The current authors questioned whether an increased risk of posttreatment adjacent-level fracture due to load shift would be maximized at a sandwich vertebra that sustained double load shift.

The purposes of the current study were to determine the incidence of adjacent-level fracture after sandwiching compared with conservative treatment and to explore the potential causative factors of sandwich vertebral fracture. An investigation of the incidence and potential risk of sandwich vertebral fracture after vertebral cement augmentation may shed additional light on the debate on adjacent-level fracture.

**MATERIALS AND METHODS**

**Patient Selection**

This study was approved by the Institutional Review Board of The First Affiliated Hospital of Soochow University. Between February 2006 and October 2010, seven hundred eighty-six patients with intractable painful osteoporotic thoracolumbar fractures were hospitalized at the same institution. All patients who underwent conservative treatment (n=182) or who had 1 sandwich level (n=47) were studied retrospectively. A sandwich vertebra was regarded as an intact vertebral body located between 2 previously cemented vertebrae (Figure 1).

Further inclusion criteria were patients (1) older than 60 years with primary osteoporosis, (2) with a sandwich vertebral body not sustaining fragile fracture before initial surgery, and (3) who underwent conservative treatment for 2 or more vertebral compression fractures. Consequently, 111 patients with a single-level fracture in the conservative group and 5 with underlying diseases other than benign osteoporotic vertebral compression fracture (3 metastatic carcinoma and 2 multiple myelomas) in the sandwich group were excluded from the study, leaving 113 patients in the study cohort.

**Evaluation of Adjacent-level/Sandwich Fracture**

Follow-up examination included lateral and anteroposterior spinal radiographs taken in the supine position within 1 month after discharge, after 3 months, and every 3 months thereafter. If the patient reported back pain during follow-up, lateral and anteroposterior spinal radiographs and magnetic resonance imaging (MRI) were performed to confirm the presence of a new vertebral fracture. Radionuclide bone scan was alternatively performed in cases where MRI was contraindicated. A subsequent vertebral fracture was diagnosed when the following 2 criteria were fully met: (1) the patient experienced new-onset back pain that matched imaging findings, and (2) lateral radiographs revealed any loss of vertebral body height compared with baseline lateral radiographs; MRIs revealed narrow replacement with edema at the same level; or 99mTc-labeled nuclear bone scan revealed hot uptake of the vertebral body at an anatomic level corresponding with the pain and tenderness.

**Data Collection**

Rate of subsequent sandwich/adjacent vertebral fracture between the 2 groups was investigated. A demographic database was created containing patient age, sex, weight, height, body mass index, follow-up period, and location of sandwich level (T10-L2 or nonT10-L2 junction). Surgical variables included cement injection procedure (percutaneous vertebroplasty or balloon kyphoplasty), surgical approach (through uni- or bilateral pedicles), volume of cement injected into the painful vertebrae, cement leakage into the intervertebral disk, cumulative number of treated levels, and pre- and postoperative kyphotic angulation of the sandwich region (Figure 1). Sagittal kyphotic angulation measurement was performed by the same radiograph technician.

**Statistical Analysis**

The incidence of sandwich vertebral fractures was compared with that of subsequent adjacent-level fractures in the conservative group. The subgroup with sandwich-level fractures was initially compared with those without sandwich-level fractures using an independent-
sample t test and chi-square test to evaluate the causative factors of sandwich vertebral fracture. The final variables with statistical or borderline statistical significance were arranged for further evaluation by stepwise logistic regression. Data were analyzed using the PASW version 17 software (SPSS, Inc, Chicago, Illinois). A P value less than .05 was considered statistically significant.

RESULTS
Mean follow-up was 22.3 months (range, 13-37 months). In the conservative group of 71 patients with 156 initial fractures, 11 adjacent fractures were identified, with a new onset of pain ranging from 33 days to 26 months after medical intervention. In the sandwich group, 42 patients had 109 vertebrae bodies managed with cement infiltration, and 9 of the 42 sandwich levels developed vertebral fatigue fractures. Figure 2 shows the distribution of sandwiching at each vertebral level. Among the 9 patients, 4 underwent a further kyphoplasty for pain relief (Figure 3). The remaining 5 patients denied a secondary procedure because the back pain was not severe (Figure 4).

The overall cohort incidence of sandwich vertebral fracture per patient was 21.43% (9/42), whereas the incidence of adjacent vertebral fracture in the conservative group was 15.49% (11/71). The difference in incidence was not significant (P = .424). Table 1 shows that patient demographics did not correlate statistically with the risk of sandwich vertebral fracture. The final variables with statistical significance that were rendered for a multiple logistic regression included pre- and postoperative local kyphosis angle (Table 2). The results revealed that only preoperative kyphotic angulation was the variable positively associated with sandwich vertebral fracture during follow-up (P = .021).

DISCUSSION
Adjacent vertebral fracture secondary to vertebroplasty or kyphoplasty has been widely discussed in previous studies. The reported rate of adjacent vertebral fracture after vertebroplasty varies from 7.4% to 52%, whereas the rate...
after kyphoplasty is 6.5% to 29%.

No consensus exists on whether subsequent adjacent fractures are cement infiltration related or part of the natural progression of osteoporosis. Multiple covariate analysis, including patient characteristics and surgical variables, were performed in previous clinical studies to evaluate the risk factors for development of adjacent vertebral fracture. The presence of more than 2 preexisting vertebral compression fractures, location of the adjacent vertebra in the TL junction, steroid dependency, wedge deformity of the fractured vertebra, and cement leakage into the disk were shown to indicate the increased risk of developing adjacent-level fractures. Some clinical trials deduced that the development of an adjacent-level fracture was related to altered biomechanics in the treated area of the spine.

To explore the possible causative mechanism of new fractures at adjacent levels, a series of human cadaver studies and finite element analyses was performed to examine the biomechanical effects of vertebral cement reinforcement. In finite element models of single lumbar functional spinal units, Baroud et al reported that filling vertebrae with bone cement may substantially alter the stiffness and induce a load shift across the intervertebral disk and that the resultant increased inward bulge of the endplate adjacent to the augmented one may be the cause of adjacent fractures. Different biomechanics trends were observed in these studies because specimen levels and test setups in the investigations were different. Furthermore, many effects, such as spinal posterior elements,

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Table 1

<table>
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<tr>
<th>Characteristic</th>
<th>SVF (n=9)</th>
<th>No SVF (n=33)</th>
<th>P</th>
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<tr>
<td>Sex, No. F:M</td>
<td>6:3</td>
<td>26:7</td>
<td>.573</td>
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<tr>
<td>Mean age, y</td>
<td>73.56±5.2</td>
<td>70.73±8.67</td>
<td>.359</td>
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<tr>
<td>Mean weight, kg</td>
<td>50.27±10.64</td>
<td>51.67±7.69</td>
<td>.661</td>
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<tr>
<td>Mean height, m</td>
<td>1.55±0.10</td>
<td>1.56±0.07</td>
<td>.635</td>
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<tr>
<td>Mean BMI, kg/m²</td>
<td>22.18±4.69</td>
<td>21.29±2.86</td>
<td>.600</td>
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<tr>
<td>No. of T10-L2 junctions/ nonT10-L2 junctions</td>
<td>5/4</td>
<td>21/12</td>
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<tr>
<td>Mean cumulative treated levels</td>
<td>2.67±0.71</td>
<td>3.12±1.32</td>
<td>.328</td>
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<tr>
<td>Mean preoperative kyphotic angulation, deg</td>
<td>21.11±7.11</td>
<td>13.27±4.95</td>
<td>.000</td>
</tr>
<tr>
<td>No. of PVP/BKP</td>
<td>3/6</td>
<td>16/17</td>
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</tr>
<tr>
<td>No. of unilateral/bilateral surgeries</td>
<td>7/2</td>
<td>23/10</td>
<td>.953</td>
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<tr>
<td>No. of cement disk leakage/ no cement disk leakage</td>
<td>1/8</td>
<td>7/26</td>
<td>.257</td>
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<td>Mean cement injected, mL</td>
<td>8.39±1.65</td>
<td>9.06±2.67</td>
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<td>Mean postoperative kyphotic angulation, deg</td>
<td>13.00±5.52</td>
<td>8.85±4.14</td>
<td>.011</td>
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</table>

Abbreviations: BKP, balloon kyphoplasty; BMI, body mass index; deg, degrees; PVP, percutaneous vertebroplasty; SVF, sandwich vertebral fracture; TL, thoracolumbar.

*Statistical significance set at P<.05.
Table 2

<table>
<thead>
<tr>
<th>Equation Variables</th>
<th>95% CI for Exp(B)</th>
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<tr>
<td><strong>Step 1a</strong></td>
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<tr>
<td>Pre Cobb</td>
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<tr>
<td>Post Cobb</td>
<td>.329</td>
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<tr>
<td>Constant</td>
<td>5.864</td>
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</table>

Abbreviations: B, estimate; Exp(B), standardized estimate; CI, confidence interval; Cobb, Cobb angle; df, degrees of freedom; Post, postoperative; Pre, preoperative; SE, standard error; Wald, Wald chi-square.

*Statistical significance was defined as P < .05.

paraspinal muscles, and degenerated adjacent intervertebral disks, have not been taken into account in the functional spinal unit models.

The current authors questioned whether an increased risk of posttreatment adjacent-level fracture due to load shift would be maximized at a sandwich vertebra that sustained double load shift. The current study assessed the incidence of sandwich vertebral fracture and of subsequent adjacent-level fracture. The results showed that the difference in incidence was not significant between the conservative and sandwich groups (P = .424). The sandwich vertebra, did not fracture more often than the conservative group. Given the progressive nature of osteoporosis, it is possible that adjacent fractures after vertebral reinforcement are the natural course of osteoporosis, especially when adjacent vertebrae have similar morphological properties.

In the current study, the risk of sandwich vertebral fracture increased significantly with a greater degree of preoperative local kyphotic angulation at the sandwich region (P = .021). The authors ascribed it to altered biomechanics in the treated area of the spine due to the resistant kyphosis. When a wedge-shaped compression fracture occurs, the kyphotic spinal posture shifts the center of gravity of the upper body anteriorly, and, therefore, a larger back extensor countermovement is required to maintain static equilibrium of the trunk by resisting the flexion moment imposed by gravity and any mass carried anterior to the spine. Yuan et al. reported that if the normal spinal sagittal alignment after fracture is not restored, it increases the forward bending moment and the stresses around the apex of the deformity. When the weakened bone at vertebral levels adjacent to the apical level cannot withstand the increased stresses, adjacent fracture occurs. Balloon kyphoplasty for osteoporotic vertebral compression fractures does not increase, but rather may serve to reduce, the incidence of subsequent vertebral fractures for osteoporosis.

This study had several inherent limitations. First, decreased bone mineral density is known to be a potential risk factor for pathologic vertebral compression fracture. Nevertheless, this study did not fully characterize the effects of bone density values. Second, osteoporosis therapies that may play an important role in preventing subsequent adjacent-level fracture were not included in the tested variables. This may have been a source of bias in the investigation. Third, the sample size of this investigation was small because sandwich vertebral fracture was strictly defined as a pinched vertebra located between 2 previously cemented vertebrae. Among the 786 patients in the authors’ institution who sustained painful thoracolumbar fractures, only 42 met the definition of sandwich vertebral fracture. Thus, further studies are needed to define the outcome of sandwich vertebral fractures.

References


