The Effect of Postural Correction and Subsequent Balloon Inflation in Deformity Correction of Acute Osteoporotic Vertebral Fractures

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Objective: To determine deformity correction by postural correction and subsequent balloon inflation in acute vertebral compression fractures (OVCFs) and to examine the effect of bone mineral density on deformity correction.

Methods: A total of 50 acute OVCFs received balloon kyphoplasty. Lateral radiographs were taken and analyzed at five different time points: 1) preoperative, 2) after placing the patient in prone hyperextended position, 3) after balloon inflation, 4) after deposition of the cement, and 5) postoperative. All fractures were analyzed for height restoration of anterior (Ha), middle (Hm) and posterior (Hp) vertebra as well as Cobb angle and Kyphotic angle. The bone mineral density (BMD) of lumbar spine was measured by dual-energy X-ray absorptiometry. According to the T-score, the patients were divided into two groups which were osteoporosis group and osteopenia group.

Results: Postoperative measurements of Ha, Hm and the Cobb angle demonstrated significant reduction of 4.62 mm, 3.66 mm and 5.34° compared with the preoperative measurements, respectively (each \( p < 0.05 \)). Postural correction significantly increased Ha by 5.51 mm, Hm by 4.35 mm and improved the Cobb angle by 8.32° (each \( p < 0.05 \)). Balloon inflation did not demonstrate a significant improvement of Ha, Hm or the Cobb angle compared with baseline prone hyperextended. Postural correction led to greater improvements of Ha, Hm and Cobb angle in osteoporosis group than osteopenia group (each \( p < 0.05 \)).

Conclusion: In acute OVCFs, the height restoration was mainly attributed to postural correction rather than deformity correction by balloon inflation. BMD affected deformity correction in the process of postural correction.

Key Words: Osteoporosis · Bone mineral density · Vertebral fracture · Balloon kyphoplasty · Height restoration.
vertebral height and Cobb angle, and Kyphotic angle. The aim of the present study is to evaluate whether balloon inflation restores sagittal alignment after postural correction in acute OVCFs. This study also tests the hypothesis that the degree of deformity correction is related to BMD in the patients with OVCFs.

MATERIALS AND METHODS

Patients

This is a prospective radiology study of all consecutive balloon kyphoplasties performed in our unit over the previous year (February 2012 to February 2013). Fifty single-level OVCFs were treated by balloon kyphoplasty. Selection criteria for kyphoplasty were: 1) presence of OVCFs, 2) sufficient pain to impair activities of daily living, 3) absence of neurologic symptoms, 4) sufficient medical stability to tolerate general anesthesia, and 5) absence of contraindication. Patients were included only when their lumbar-spine BMD T-scores were lower than -1. Thirty-eight (77.8%) patients were women and twelve (22.2%) were men. Mean patient age was 71.6 years (range, 60–82 years). The fractures occurred between T10 and L3. These patients were operated within 4 weeks of sustaining the fractures. Fracture compression was severe in 6, moderate in 24, and mild in 20 OVCFs. Fracture severity was determined semiquantitatively according to Genant classification, which was characterized as mild (20–25%), moderate (25–40%) or severe (>40%) vertebral compression fracture at any posterior, middle, or anterior point. The fracture was detected in preoperative standing anteroposterior and lateral radiographs. Further examinations were performed to provide an evidence of edema in the fractured vertebral body on T2-weighted images and to evaluate the phenomenon of intravertebral vacuum cleft by magnetic resonance imaging (MRI) scan in all patients.

Technique of kyphoplasty

In the operating room, patients were placed in prone position with the spine extended by chest and pelvic bolsters and under general anesthesia condition. Kyphoplasty was performed through a transpedicular approach by using two 11-gauge bone biopsy needles. Inflatable Bone Tamps (Shangdong Guanlong Medical Utensils Co., Ltd, Shangdong, China) were placed bilaterally into the vertebral body through working cannulas and inflated in the center of the vertebral body. Inflation continued until the balloon reached 300 psi (1 psi=6895 Pa) or the maximal balloon volume was reached. After the balloons were withdrawn, polymethylmethacrylate cement (Tianjin Synthetic Materials Research Institute, Tianjin, China) was injected into the fractured vertebral body and its volume was recorded. The cement was allowed to cure for 5 minutes until it had a tooth paste viscosity to lower the risk of cement extravasation. Simultaneous c-arm fluoroscopy was used for guiding the needle insertion and balloon inflation.

Assessment of vertebral body height and kyphosis

Lateral radiographs were taken and analyzed at five different time points: 1) preoperative (standing lateral X-ray), 2) after placing the patient in prone hyperextended position, 3) after bilateral balloon inflations, 4) after deposition of the cement, 5) postoperative (standing lateral X-ray). At each time point, we calculated vertebral height in the anterior (Ha), middle (Hm), and posterior (Hp) portions of the treated vertebra, Kyphotic angle and Cobb angle (Fig. 1). Ha was the distance between the most anterior-superior and anterior-inferior endplate margins. Hm was the distance between the midpoint of the two superior endplates and midpoint of the two inferior endplates in the middle part of vertebra. Hp was the distance between the most posterior-superior and posterior-inferior endplate margins. Kyphotic angle was the angle in degrees defined by the intersection of superior and inferior endplate of the fractured body. For determination of the Cobb angle, measurement was taken from the superior endplate of the vertebra one level above the treated vertebra to the inferior endplate of the vertebral body one level below the treated vertebra. Preoperative compression ratio was defined as the ratio of anterior height of fractured vertebral body to average anterior height of the cranial and caudal vertebrae. Vertebral height and sagittal alignments were measured on Pictures Archiving and Communications System (INFINITT, Seoul, Korea). The blinded measurements were repeated 2 times at 2-week intervals. The precision error was calculated for each dimension Ha, Hm, Hp, Kyphotic angle, and Cobb angle, 15 randomly selected

Fig. 1. Measurement of anterior (Ha), middle (Hm), and posterior (Hp) vertebral height and Cobb angle, and Kyphotic angle.
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tended position, Ha improved by 5.51±2.64 mm, Hm by 4.35±2.73 mm, Hp by 3.79±3.22 mm, Kyphotic angle by 5.01±2.74°, and Cobb angle by 8.32±3.69° (each p<0.001).

Effect of kyphoplasty

The average balloon inflation pressure was 180 psi (range, 120–300 psi). The average volume of cement applied to the vertebra was 4.6 mL (range, 3–6 mL). Balloon inflation did not contribute to a significant vertebral height increase in anterior, middle or posterior portion after postural reduction (each p>0.05) (Fig. 2). In addition, no significant improvement was detected in Kyphotic angle or Cobb angle (each p>0.05) (Fig. 3). Subsequent placement of cement in the vertebra did not alter the degree of reduction by means of Ha, Hm, Hp, Kyphotic an-

BMD measurement

The bone mineral density for spine lumbar was measured by dual-energy X-ray absorptiometry (DEXA, Lunar Radiation, Madison, WI, USA) and the results were expressed as T-scores. Osteopenia is defined as a BMD that is between 1 and 2.5 SDs below the average for the reference population. Osteoporosis is defined as a BMD that is 2.5 SDs or more below the young adult mean.20 According to the T-score for lumbar-spine BMD, the patients were divided into two groups, which were osteoporosis group (27 cases) and osteopenia group (23 cases).

Statistics

Statistical analysis was performed with SPSS 16 software (SPSS Inc., Chicago, IL, USA). For numeric data, mean±SD were calculated. To test for precision in measurements, we used the intra-class correlation. Comparisons between different time points were performed using a paired sample t-test. Comparisons between different groups were performed using the independent sample t-test or chi-square test. Differences were considered as statistically significant with a p value of less than 0.05.

RESULTS

Precision

Precision errors expressed as SD were 2.2 mm, 2.7 mm, 2.3 mm, 2.8°, and 4.2° for Ha, Hm, Hp, Kyphotic angle and Cobb angle, respectively. The intra-class correlations were 0.93, 0.90, 0.96, 0.88, and 0.86 for the Ha, Hm, Hp, Kyphotic angle and Cobb angle, respectively.

Overall height reduction and sagittal realignment

The overall height reduction and sagittal realignment postoperatively compared with preoperatively was showed in Fig. 2 and 3. Ha and Hm improved significantly from 20.84±5.06 mm (range, 9.42–33.08 mm) to 25.46±4.62 mm (range, 14.58–33.80 mm), and from 17.79±4.51 mm (range, 8.10–24.81 mm) to 21.45±4.18 mm (range, 9.49–27.6 mm), respectively. Hp improved from 27.36±4.82 mm (range, 19.82–37.46 mm) to 29.93±4.24 mm (range, 19.88–42.6 mm) without significance. The Kyphotic angle was reduced significantly from 10.27±4.31° (range, 2.5–18.74°) before surgery to 6.43±3.53° (range, 0.88–12.30°) after surgery. The Cobb angle was reduced significantly from 12.98±6.89° (range, 5.68–24.24°) before surgery to 7.64±5.91° (range, 6.35–22.03°) after surgery.

Dynamic fracture mobility

Placement of patients in prone hyperextended position led to a significant restoration of vertebral height and segmental kyphosis (Fig. 2, 3). After placing the patient in prone hyperex-

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Table 1. Effect of BMD on height restoration and sagittal realignment

<table>
<thead>
<tr>
<th></th>
<th>Osteoporosis group (BMD &lt;-2.5, n=27)</th>
<th>Osteopenia group (BMD &gt;-2.5, n=23)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative</td>
<td>Prone</td>
</tr>
<tr>
<td>Ha (mm)</td>
<td>20.05±4.52</td>
<td>26.14±4.33*</td>
</tr>
<tr>
<td>Hm (mm)</td>
<td>16.88±4.36</td>
<td>22.03±3.73*</td>
</tr>
<tr>
<td>Hp (mm)</td>
<td>26.92±3.98</td>
<td>30.99±4.69*</td>
</tr>
<tr>
<td>Kyphotic angle (°)</td>
<td>10.53±4.51</td>
<td>4.89±3.98*</td>
</tr>
<tr>
<td>Cobb angle (°)</td>
<td>13.35±5.34</td>
<td>3.75±4.89*</td>
</tr>
</tbody>
</table>

Values are presented as mean±SD. *p<0.01 for prone vs. preoperative in each group, †p<0.05 for improvement in osteoporosis group vs. improvement in osteopenia group. BMD : bone mineral density, Ha : anterior vertebral height, Hm : middle vertebral height, Hp : posterior vertebral height

gle and Cobb angle (each p>0.05) (Fig. 2, 3). Moreover, patients lost reduction after cementing to post-operative films, with Ha losing 0.97±0.33 mm, Hm by 0.86±0.31 mm, Hp by 1.43±0.52 mm, Kyphotic angle by 1.51±0.44° and Cobb angle by 3.51±1.02° (each p<0.05).

Effect of BMD

We evaluated the effect of postural correction on height restoration and sagittal realignment in the osteopenia and osteoporosis groups, respectively (Table 1). In both groups, postural correction improved Ha, Hm, Hp, Kyphotic angle and Cobb angle significantly (each p<0.05). Moreover, postural correction led to greater improvements of Ha, Hm, Kyphotic angle and Cobb angle in osteoporosis group compared with osteopenia group (each p<0.05). In contrast, balloon expansion did not significantly improve vertebral height and sagittal alignment in either group and no significant difference of improvement was noticed between the two groups. Preoperative compression ratio was 62±23% in osteoporosis group, which was more severe than 79±9% in osteopenia group (p<0.01). Intravertebral vacuum clefts occurred in 11 of 27 vertebrae in osteoporosis group and 8 of 23 vertebrae in osteopenia group (p<0.05).

DISCUSSION

Dynamic fracture mobility raises concern in OVCFs as it implies complete corticocancellous disruption and permits the vertebral height restoration after postural reduction17,18. As the injury of OVCFs produced is an anterior wedge fracture, postural reduction in prone hyperextended position can re-expand the compressed anterior column19. Intra-operative positioning with bolsters under the upper chest and the iliac crests could lead to clinically significant height restoration16,17,19. Voggenreiter20 reported that placement of the patient in this way produced a significant reduction of Cobb angle by 6.4°, Kyphotic angle by 3.7°, Ha by 19%, Hm by 16% and Hp by 16%. Cawley et al.21 put forward a technique which maintained the leverage created by pelvic extension as well as bolstering the chest and pelvis. Analysis of their data revealed an 8.3% increase in anterior vertebral height and a 4.9° reduction in Cobb angle. By using four small bolsters, we demonstrated improvements of 8.3° in Cobb angle, 5.0° in Kyphotic angle, 26.4% in Ha, 24.5% in Hm and 13.9% in Hp in our intra-operative postural correction. We suggested that placements of bolsters under the chest and pelvis provided a satisfactory spine extension and contributed to a significant deformity reduction.

Balloon kyphoplasty has the potential to relieve the fracture related pain and correct the segmental deformity. A few studies showed that balloon kyphoplasty was effective in deformity correction of OVCFs and attributed the height restoration to the balloon inflation13,15,22. Voggenreiter23 found that balloon inflation achieved a deformity correction with the Cobb angle reducing by 3.5° compared with baseline prone hyperextended, Ha improving by 19% and Hm by 18%, respectively. In his series, a majority of OVCFs (61.5%) were severe compression fractures. Kim et al.11 attempted to determine the efficacy of kyphoplasty after postural reduction in severe OVCFs and observed significant improvements of Ha by 13 mm and Hm by 9 mm, respectively. Thus, kyphoplasty could further achieve significant height restoration after the process of postural reduction in severe OVCFs.

The degree of the kyphotic deformity seems to be the most significant factor affecting postural versus balloon inflation24. Table 2 summarises the corrections achieved by postural correction and balloon inflation in various studies. Cawley et al.25 suggested that postural correction rather than balloon inflation led to a significant restoration of vertebral height which was in conflict with several other studies. In his study, the mild and moderate OVCFs were in the majority with preoperative compression ratio of 72%. We also found that the treated vertebra reached maximal restoration after intra-operative postural reduction and little height restoration was observed by subsequently using balloon kyphoplasty in mild or moderate OVCFs. In the current study, eighty-eight percent of these OVCFs were mild and moderate in fracture severity with preoperative compression ratio of 70%.

Fracture chronicity is a variable affecting postural versus balloon assisted reduction. The adaptation of balloon kyphoplasty is originally for patients who have the delayed union or non-union vertebral fractures in sub-acute or chronic phases (more than 6–8 weeks after injury). As kyphoplasty rapidly reduces pain and improves function, disability, and quality of life, it is now in common used for the treatment of acute vertebral compression fractures18,26. Feltes et al.27 found that kyphoplasty failed
### Table 2. Efficacy of postural correction and subsequent procedures (balloon kyphoplasty)

<table>
<thead>
<tr>
<th>Author</th>
<th>Age VCF</th>
<th>Height restoration (postural)</th>
<th>Kyphosis improvement (postural)</th>
<th>Height restoration (PKP)</th>
<th>Kyphosis improvement (PKP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shindle et al.</td>
<td>340 days</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Kim et al.</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Voggenreiter et al</td>
<td>T9-L2/5.2 mL (leakage 36%)</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Cawley et al.</td>
<td>T11-L4/NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

Values are presented as mean±SD unless otherwise indicated. Test for heterogeneity. *p<0.01, **p<0.001. NR: not reported. Ha: anterior vertebral height, Hm: middle vertebral height, Hp: posterior vertebral height, Ka: Kyphotic angle, Cobb: Cobb angle, Pre: pre-postural correction or pre-surgery, Post: post-postural correction or post-surgery, NVB: normal vertebral height, PKP: percutaneous kyphoplasty.

### CONCLUSION

In acute osteoporotic vertebral compression fractures, the height restoration was mainly attributed to postural correction rather than deformity correction by balloon inflation. The degree of deformation correction by balloon inflation seemed to be an important factor affecting height restoration. The current study has some limitations. First, the number of patients with dynamic compression fractures is limited. Second, we did not evaluate the long-term maintenance of height restoration. The number of patients in the current study has some limitations. First, the number of patients with dynamic compression fractures is limited. Second, we did not evaluate the long-term maintenance of height restoration. The current study has some limitations. First, the number of patients with dynamic compression fractures is limited. Second, we did not evaluate the long-term maintenance of height restoration. The current study has some limitations. First, the number of patients with dynamic compression fractures is limited. Second, we did not evaluate the long-term maintenance of height restoration. The current study has some limitations. First, the number of patients with dynamic compression fractures is limited. Second, we did not evaluate the long-term maintenance of height restoration. The current study has some limitations. First, the number of patients with dynamic compression fractures is limited. Second, we did not evaluate the long-term maintenance of height restoration.