INTRODUCTION:
Percutaneous vertebroplasty is a minimally invasive, radiologically guided therapeutic procedure whereby cement is injected into structurally weakened vertebrae. Vertebral pathology treated by this technique includes osteoporotic fractures, hemangiomas, and lytic metastases. Vertebral with lytic metastases have an elevated risk of burst fracture which can cause bone from the posterior wall and intravertebral tumor to be retropulsed into the spinal canal, resulting in neurologic compromise. Axial loading of metastatically involved vertebrae has been shown to cause internal pressurization, increased surface tensile hoop strains, and narrowing of the spinal canal due to bulging of the vertebral body1. The aim of prophylactic percutaneous vertebroplasty in the metastatic spine is to reduce pain and the risk of burst fracture. The purpose of this study was to investigate the biomechanical stability of cadaveric spines with simulated metastases, pre and post vertebroplasty.

METHODS:
Six fresh-frozen cadaveric thoracolumbar spinal motion segments were harvested (80.3 ± 8.9 years, 62-100), x-rayed and measured. A canal displacement gauge was attached between the posterior arch and the midpoint of the posterior vertebral body wall of the central vertebrae of each spinal motion segment (T12-L1-L2 or L3-L4-L5). Intact specimens were potted and axially loaded to 800N at a rate of 1600N/s on an MTS Bionix 858 servohydraulic testing machine (MTS, Eden, MN). To create a simulated lesion, a central core of cancellous bone was removed from the vertebral body, and the defect filled with soft tissue tumor (Defect size: 11.5% ± 3% of the vertebral body volume). Trabecular density was physically measured from the removed bone cores. Specimens with the simulated metastases were then retested under the axial loading protocol described above. Percutaneous vertebroplasty was performed on each specimen using a transpedicular technique under fluoroscopic guidance. Eight mL of cement (Simplex P, Howmedica USA) was injected at a rate of 3mL per minute into each specimen. The percentage change in load induced canal narrowing (LICN) was statistically analyzed using a repeated measures ANOVA design (SPSS).

RESULTS:
Vetebral with simulated metastases exhibited significantly higher LICN than intact specimens 247% ± 119% (p<0.05) (Table 1). However post vertebroplasty, while half of the vertebrae exhibited reduced LICN compared to the simulated tumor configuration, the other half had higher LICN. Load to failure for the specimens post vertebroplasty averaged 3141N ± 1199N.

<table>
<thead>
<tr>
<th>#</th>
<th>Tumor Size %</th>
<th>ΔLICN Tumor vs. Intact</th>
<th>ΔLICN Post VP vs. Tumor</th>
<th>Load to Failure Post VP (N)</th>
<th>Cement Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>181%</td>
<td>750%</td>
<td>4000</td>
<td>L, A</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>179%</td>
<td>129%</td>
<td>2000</td>
<td>L, A</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>430%</td>
<td>156%</td>
<td>2211</td>
<td>L, A</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>338%</td>
<td>36%</td>
<td>3298</td>
<td>L, A, P</td>
</tr>
<tr>
<td>5</td>
<td>14</td>
<td>106%</td>
<td>49%</td>
<td>2308</td>
<td>L, A, P</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>249%</td>
<td>98%</td>
<td>5030</td>
<td>L, A, P</td>
</tr>
</tbody>
</table>

Table 1. The percentage change in load induced canal narrowing (LICN) is shown for metastatically involved vs. intact specimens and for post vertebroplasty vs. tumor specimens. Load to failure is shown for post vertebroplasty specimens. Cement location with respect to the lesion was documented following vertebral sectioning as lateral (L), anterior (A), or posterior (P).

All specimens had tumor tissue present within the defect post vertebroplasty. Cement was found lateral and anterior to remaining tumor tissue in all specimens. Only 3 specimens were found to have cement posterior to the lesion. All specimens exhibited failure in burst fracture patterns with retropulsion of tissue into the spinal canal.

DISCUSSION:
Load induced canal narrowing following tumor creation was significantly higher than that of the intact specimens (p<0.05). This agrees with previous findings demonstrating that the presence of tumor increases vertebral bulge and the risk of burst fracture. Following percutaneous vertebroplasty, half of the specimens were found to have a reduction in LICN relative to the vertebra with simulated metastases, while the other half demonstrated an increase in LICN. Cement fill patterns and the presence of tumor in post vertebroplasty were examined as a possible explanation for the difference in posterior wall stabilization. In all cases, vertebroplasty did not completely fill the lytic defect with cement. Instead, cement moderately compressed the tumor and filled cancellous bone around the lesion. Specimens with reduction in LICN post vertebroplasty were found to have cement posterior to the tumor, while specimens with an increase in LICN had cement only lateral and anterior to the lesion. The presence of a posterior rigid cement wall may reduce posterior bulge of the remaining tumor under load. In contrast, with cement fill anterior and lateral to the tumor only, the rigid presence of cement in these locations may lead the remaining tumor to cause more vertebral bulge posteriorly under load. It should be noted that specimen #1 experienced a fracture of the lateral portion of the posterior wall during vertebroplasty which may account for the large LICN value reported post vertebroplasty.

Independent of the pattern of fill, the specimens exhibited load to failure values in the range of that found in previous studies examining intact osteoporotic vertebrae tested to failure and retested following percutaneous vertebroplasty2,3. However, our findings post vertebroplasty may be higher than load to failure values expected for similar low-density vertebrae with metastatic involvement prior to stabilization. The mode of failure of our metastatically involved specimens post vertebroplasty was consistent with a burst fracture pattern, with compromise of the middle column.

CONCLUSION:
Location of the cement after injection relative to the tumor is important in determining whether or not vertebral wall motion is reduced or increased with percutaneous vertebroplasty. Percutaneous vertebroplasty is effective in decreasing LICN for specimens with lytic metastases if the tumor is surrounded posteriorly with cement. However, clinically injecting cement in the posterior third of the vertebral body should be avoided in order to reduce potential complications resulting from extravasation of cement into the spinal canal. Potentially, eliminating the presence of tumor prior to injection, may facilitate filling of the defect, and reduce LICN without additional risk to the spinal canal.

REFERENCES:

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