Intravertebral Cleft Sign on Fat-suppressed Contrast-enhanced MR: Correlation With Cement Distribution Pattern on Percutaneous Vertebroplasty

Masaki Oka, MD, PhD, Masaki Matsusako, MD, PhD, Nobuo Kobayashi, MD, Akihiro Uemura, MD, Yuji Numaguchi, MD, PhD

Rationale and Objectives. Filling intravertebral clefts during percutaneous vertebroplasty (PVP) is considered to be important for optimal pain control. It is often difficult to detect clefts on non-contrast MR and some fractures show a solid pattern distribution of injected cement without a cleft sign on non-contrast MR. In this study, we evaluated usefulness of fat-suppressed contrast-enhanced MR to predict a solid pattern distribution of injected cement on PVP.

Materials and Methods. Twenty-six patients with 35 vertebral compression fractures due to osteoporosis were studied. We performed sagittal T1-weighted, T2-weighted and fat-suppressed contrast-enhanced T1-weighted images prior to PVP. First we evaluated the presence of fluid-filled or gas-containing clefts on non-contrast MR. Next we evaluated contrast-enhanced MR of the same vertebrae for the presence of cleft-shaped unenhanced areas within the diffuse enhancement area. We correlated MR findings with cement distribution patterns of injected cement.

Results. Based on MR findings, 35 osteoporotic fractures were divided into 3 types. Type 1 (11 fractures, 31%): There were no clefts on non-contrast MR and no unenhanced areas on contrast-enhanced MR; Type 2 (13, 37%): There were no clefts on non-contrast MR but there were unenhanced areas on contrast-enhanced MR; Type 3 (13, 37%): There were clefts on non-contrast MR and unenhanced areas on contrast-enhanced MR. Of 35 osteoporotic fractures, thirteen vertebral fractures (37%) were noted to contain clefts on non-contrast MR, while 24 vertebral fractures (69%) contained unenhanced areas on contrast-enhanced MR. Cement distributed as a solid pattern within clefts or unenhanced areas in all fractures with them.

Conclusion. Fat-suppressed contrast-enhanced MR is useful to predict a solid pattern distribution of injected cement prior to PVP.

Key Words. percutaneous vertebroplasty; cleft; contrast-enhanced MR; cement.

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Intravertebral cleft has been described as a cavity below the endplate resulting from compression trauma. Although intravertebral cleft previously was believed to represent ischemic necrosis (Kümmell’s disease) (1–5), it is currently believed to represent a region of nonunion with pseudarthrosis of the fracture (6–10). There is a high prevalence of these types of vertebral body compression fractures at the thoracolumbar junction, where there is more motion physiologically, which, in turn, may predispose to the development of nonunion and pseudarthrosis (11).

Lane et al (11) reported two patterns of cement opacification of osteoporotic compression fractures after treatment with percutaneous vertebroplasty (PVP). The most common
pattern, seen in 68% of patients, was a trabecular pattern in which the radio-opaque cement was interspersed throughout the trabecular space. The other pattern of opacification, seen in the remaining 32%, was a solid pattern of opacification in which the radio-opaque cement completely filled a large cavity. To date, there is no imaging examination with high sensitivity that will identify the latter type of compression fracture before PVP. Conventional radiographs show gas within these fractures in only a minority of cases (5,12). Noncontrast magnetic resonance (MR) may show fluid-filled clefts, but detect only half these types of vertebral fractures (11).

Contrast-enhanced MR has been used to evaluate acute compression fractures, especially in differentiation between benign and malignant compression fractures (13–15), whereas the role in PVP has not been well studied. On fat-suppressed contrast-enhanced MR before PVP, we frequently observed unenhanced areas near the fractured endplate. Because unenhanced areas have a location and shape similar to clefts seen on T2-weighted images, we speculated that the unenhanced area correlated with a solid distribution pattern of injected cement during PVP. In this study, we have undertaken a retrospective review to determine the frequency of unenhanced areas and correlate MR findings with distribution patterns of injected cement on PVP. It may be important to estimate a solid pattern of injected cement before PVP because several investigators suggested that cleft-included vertebral fractures require complete filling of the site of nonunion to achieve immobilization and pain relief (11,16–18).

MATERIALS AND METHODS

The study design was approved by our institutional review board.

Patients

Twenty-six patients with 35 vertebral compression fractures caused by osteoporosis were studied retrospectively. There were 15 women and 11 men. Patient age ranged from 70 to 93 years, with an average of 78.2 years. PVP was performed within 3 months after the onset of acute back pain in all patients; within 1 month in 17 patients and between 1 and 3 months in 9 patients. Metastatic tumors were excluded from this study based on MR findings and bone biopsy, which was performed during PVP.

Table 1

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Type 1 (n = 11)</th>
<th>Type 2 (n = 11)</th>
<th>Type 3 (n = 13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trabecular</td>
<td>11</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Solid</td>
<td>0</td>
<td>11</td>
<td>12</td>
</tr>
</tbody>
</table>

Type 1, no clefts on noncontrast MR and no unenhanced areas on contrast-enhanced MR; type 2, no clefts on noncontrast MR, but unenhanced areas on contrast-enhanced MR; type 3, clefts on noncontrast MR and unenhanced areas on contrast-enhanced MR.

PVP Procedure

PVP was performed within 3 days after the MR study. Eleven or 13 G bone biopsy needles (Osteo-site; Cook, Bloomington, IN) were used through a bilateral or unilat- eral transpedicular approach and placed into the anterior third of the vertebral body under biplane fluoroscopic control. After the needles were placed in the vertebral body, the liquid and powder polymethylmethacrylate (Cranioplasty; Codman, Raynham, MA) was mixed with sterilized barium sulfate. Cement was injected carefully under biplane fluoroscopic control during PVP.

Imaging and Analysis

Preprocedural MR was performed with a 1.5-Tesla system (Signa Horizon; GE Medical Systems, Milwaukee, WI) by using a spine-array surface coil. The imaging protocol included sagittal T1-weighted images (spin-echo; repetition time [TR], 500ms/echo time [TE], 14ms), T2-weighted images (fast spin-echo; TR, 3900/TE, 120; 18 gradient echos/shot), and fat-suppressed contrast-enhanced T1-weighted images (spin-echo, TR, 600/TE, 14).
First, we reviewed noncontrast MR (T1- and T2-weighted images) of vertebral fractures for the presence of clefts. Acute or subacute fractures showed hypointensity on T1-weighted images, and clefts were defined as oval or teardrop-shaped areas presenting marked hyperintensity (fluid collection) or signal loss (gas-containing space) on T2-weighted images within the hypointense area on T1-weighted images. The presence of gas was confirmed by means of plain radiographs. Next, we reviewed contrast-enhanced MR (fat-suppressed contrast-enhanced T1-weighted images) of the same vertebra for the presence of unenhanced areas, defined as oval or teardrop-shaped areas of nonenhancement within a diffuse enhancement area. Diffuse enhancement of a vertebral body indicates acute or subacute fracture, presumably representing edema or inflammation. The presence of osteosclerosis within fractures was confirmed by means of plain radiographs.

For postprocedural evaluation of cement distribution, conventional radiographs were used. The distribution of injected cement was classified as trabecular pattern (cement spreads along the fine bony trabeculae) and solid
Figure 3. Example of type 2 in a 75-year-old woman 2 months after the onset of acute back pain. (a) On a T1-weighted image (500/14), fractured L2 shows band-shaped hypointense areas at the center of vertebral body (arrow). (b) On a T2-weighted image (3900/120), the lesion shows inhomogeneous hypointensity that is different from the signal of fluid-filled or gas-containing cleft. No clefts are observed in fractures. (c) On a fat-suppressed contrast-enhanced T1-weighted image (600/14), L2 shows diffuse enhancement, and the unenhanced area is seen in the center. (d) On plain radiograph in the anteroposterior view after PVP, a solid distribution pattern of injected cement is observed in the unenhanced area.
pattern (cement forms a mass). We carefully correlated cement distribution patterns with MR findings, especially within clefts and unenhanced areas.

MR findings and distribution patterns of cement were assessed by means of visual inspection by two trained reviewers who were not informed about clinical data or other available images, and agreement was reached by consensus. Histological comparison was performed in one autopsy case.

RESULTS

Based on MR findings, 35 osteoporotic fractures were divided into three types (Figure 1). For type 1, there were no clefts on noncontrast MR and no unenhanced areas on contrast-enhanced MR. For type 2, there were no clefts on noncontrast MR, but there were unenhanced areas on contrast-enhanced MR. For type 3, there were clefts on noncontrast MR and unenhanced areas on contrast-enhanced MR. There were no fractures that showed clefts on noncontrast MR, but no unenhanced areas on contrast-enhanced MR. Of 35 fractures, 11 (31%) showed type 1, 11 (31%) showed type 2, and 13 (37%) showed type 3. Thirteen vertebral fractures (37%) were noted to contain clefts on noncontrast MR, whereas 24 vertebral fractures (69%) contained unenhanced areas on contrast-enhanced MR. No osteosclerosis were observed at the corresponding area to clefts or unenhanced areas.

Relationships between cement distribution patterns and MR findings are listed in Table 1. All type 1 fractures showed a trabecular pattern distribution of injected cement without a solid pattern (Figure 2). All type 2 (Figure 3) and type 3 fractures (Figure 4) showed a solid pattern of distribution, except for one. The solid pattern of distribution corresponded to the area of clefts or unenhanced areas. In the exceptional case (type 3 fracture), cement was injected in the diffuse enhancement area and did not reach the unenhanced area.

In type 2 fractures, unenhanced areas corresponded to mild to moderate hypointense areas on T2-weighted images, which were a different signal from fluid-filled or gas-containing clefts (Figure 3). In type 3 fractures, areas of clefts (fluid filled or gas containing) on T2-weighted images frequently were smaller than unenhanced areas. Of the 13 type 3 fractures, five showed fluid-filled clefts (hyperintensity) on T2-weighted images with a peripheral zone of the hypointense area surrounding the cleft (Figure 4). The other eight fractures showed fluid-filled clefts (hyperintensity) on T2-weighted images without a peripheral zone of the hypointense area.

Histological comparison was performed in one osteoporotic patient, who had a fracture at T12 with a fluid-filled cleft and a surrounding hypointense area on T2-weighted images (type 3; Figure 4). In an autopsy performed 3 months after PVP, extensive osteonecrosis was observed in the right side of the fractured vertebral bone, and mass-forming cement was located in the left.

When the needle was placed in areas of clefts or unenhanced areas, cement tended to fill them without filling diffuse enhancement areas, making a solid pattern. When the needle was placed in diffuse enhancement areas, cement tended to fill with a trabecular pattern first and then extended into the area of clefts or unenhanced areas, making a mixed pattern, ie, trabecular and solid patterns.

DISCUSSION

Intravertebral clefts associated with vertebral compression fractures previously were considered pathognomonic for avascular necrosis or Kümmell’s disease (1–5), but currently are believed to represent a region of nonunion with pseudarthrosis of the fracture (6–10). Clefts have been described on noncontrast MR as vertebral cavities filled with fluid or gas occurring at the site of fractured endplates, where compression is most severe. On T2-weighted images, clefts can be identified because of the characteristic shape and high intensity (fluid) or signal loss (gas). Clefts may be an indication of nonunion of the bone and can show movement of...
the bone with change in patient position or respiration (12). This motion can be responsible for persistent pain after actual fracture. Recent reports underscored the importance of filling clefts with cement to lead to an optimal outcome (11,16–18).

Lane et al (11) reported that of 53 opacified clefts (solid distribution) on PVP, only 28 fluid-filled clefts (52.8%) were detected on noncontrast MR. They concluded that imaging is not sensitive in detecting a solid pattern of distribution of injected cement before PVP. In this study, a solid distribution pattern was observed in all unenhanced areas, whereas without the unenhanced areas, a solid pattern was not observed. We speculate that the unenhanced area is a reliable sign to predict a solid distribution of injected cement.

We showed solid distribution of injected cement within unenhanced areas, which were not identified as clefts on unenhanced MR. Unenhanced areas excluding clefts are identified as mild to moderate hypointensity on T2-weighted images and can be seen as an isolated area or are accompanied by fluid-filled or gas-containing clefts. This hypointense area on T2-weighted images histologically may represent osteonecrosis, as proven in our autopsy case and also in biopsy series (19). Osteonecrosis and cleft are histologically different, but considered essentially the same in view of cement filling during PVP because the trabecular network is completely broken in these areas.

In type 2 fractures, a solid distribution pattern of injected cement sometimes is difficult to predict without the use of contrast enhancement. Hypointense areas on T2-weighted images (presumably osteonecrosis) may not be identified with confidence, especially when normal bone marrow does not show uniform hyperintensity, because the contrast between the lesions to normal bone marrow is decreased. For the same reason, when fat suppression is used for T2-weighted images, hypointense areas become more obscure because normal bone marrow turns into very low signal. In type 3 fractures, clefts are identified on noncontrast MR, but contrast enhancement can be useful to know the exact extent of solid distribution of injected cement.

In our experience, when the tip of needle is placed in the area of clefts, cement tends to fill them with minimal resistance. Therefore, we tend to make cement viscous to fill these clefts. This seems to help prevent cement leakage into the disc space or veins. Conversely, when the tip is placed in a diffuse enhancement area, more power usually is needed for the cement injection, and cement spreads in preserved trabecular networks. In this situation, we tend to make cement less viscous than when injecting in clefts to allow smooth cement distribution in the vertebral body. Thus, the information from contrast-enhanced MR may help predict the cement distribution pattern and plan the site of needle placement during PVP.

Benign fractures tend to show homogeneous enhancement, which probably represents edema or inflammation (14). Areas defined as diffuse enhancement may be identified on fat-suppressed T2-weighted images or short inversion time inversion recovery (STIR) images as diffuse hyperintensity. A previous report indicated that fat-suppressed contrast-enhanced T1-weighted images are superior to STIR in the detection of bone marrow abnormalities of the foot and ankle, but diagnoses determined with MR findings are equal with both sequences (20). In our cases with fat-suppressed contrast-enhanced T1-weighted images, diffuse enhancement areas could be identified easily because hyperintensity of normal bone marrow on T1-weighted images becomes very low signal. Fat-suppressed contrast-enhanced MR may be especially useful in cases of multiple fractures because new or noncalcified unhealed fractures can be identified readily.

In conclusion, cement distribution patterns on PVP can be predicted from MR findings. Fat-suppressed contrast-enhanced MR is important to detect unenhanced areas in which cement distributes as a solid pattern.

REFERENCES

11. Lane JI, Maus TP, Wald JT, Thielen KR, Bobra S, Luetmer PH. Intra-
vertebral clefts opacified during vertebroplasty: pathogenesis, technical
implications, and prognostic significance. AJNR Am J Neuroradiol

cleft: changes in content after supine positioning. Radiology 1993; 187:
483–487.

to osteonecrosis or malignancy: appearance on unenhanced and gado-

14. Shin TTF, Huang KM, Li YW. Solitary vertebral collapse: distinction
between benign and malignant causes using MR patterns. J MRI 1999;
9:635–642.

15. Jung HS, Jee WH, McGauley TR, Ha KY, Choi KH. Discrimination of
metastatic from acute osteoporotic compression spinal fractures with

16. Mathis JM. Percutaneous vertebroplasty: complication avoidance and

17. Peh WCG, Gelbart MS, Gilula LA, Peck DD. Percutaneous
vertebroplasty: treatment of painful vertebral compression fractures
with intraosseous vacuum phenomena. AJR Am J Radiol 2003; 180:
1411–1417.

18. Kim DY, Lee SH, Jang JS, Chung SK, Lee HY. Intravertebral vacuum
phenomenon in osteoporotic compression fracture: report of 67 cases
with quantitative evaluation of intravertebral instability. J Neurosurg

Results in Percutaneous Vertebroplasty: Correlation With MR Findings.

and ankle: STIR versus T1-weighted contrast enhanced fat-suppressed