Are Non-contrast MR Images enough for Detection of Fracture Levels Prior to Percutaneous Vertebroplasty in Patients with Osteoporosis?

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Summary

We evaluated the detectability of painful vertebral compression fractures (VCFs) on different MRI protocols in 40 osteoporotic patients with thoraco-lumbar osteoporotic vertebral fractures. Five hundred and ten thoracic and lumbar vertebrae in 40 patients were evaluated. All patients underwent percutaneous vertebroplasty. Vertebral fractures were found in 126 (24.7%) of 510 vertebrae. Healed vertebral fractures were found in 33 (26.2%) of 126 vertebral fractures. Painful osteoporotic VCFs was found in 93 (73.8%) of 126 fractures. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of contrast-enhanced MR images, and the non-contrasted combined protocol (including T1-weighted, T2-weighted and STIR images) for the detection of painful osteoporotic VCFs were all more than 90%. Therefore, the non-contrasted combined protocol can be used for detection of painful osteoporotic VCFs prior to percutaneous vertebroplasty, unless there are conditions where contrast-enhanced MR is needed to rule out other causes of VCFs.

Introduction

Osteoporotic thoracolumbar vertebral compression fractures are usually indicated for vertebroplasty (VP) if focal, intense or deep back pain persists despite bed-rest and pain control with analgesics¹. Painful vertebral compression fractures (VCFs) usually have at least one of the following features on radiographs and/or MR images: progressively decreased vertebral body height, intravertebral clefts, and bone marrow edema¹⁻⁹.

Healed osteoporotic VCFs without bone marrow edema and intravertebral clefts are usually not indicated for VP because these patients usually experience little or no pain relief after VP^{1-3,5,7}. Radiographs and magnetic resonance imaging can help determine the site of painful osteoporotic VCFs if pain and tenderness on palpation or knocking of the spinous process was mild or unclear⁸.

In general, fractures with bone edema showed contrast enhancement on contrast-enhanced T1-weighted images⁸. We usually find enhancement on contrast-enhanced T1-weighted images and observe that they correlate with painful VCFs. The risk of allergy to intravenous administration of gadolinium-related MR contrast media is rare. However, recent publications suggest that patients with renal insuffi-

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Figure 1 A 66-year-old man with painful osteoporotic vertebral compression fractures (VCFs). Fat-suppressed contrast-enhanced T1-weighted MR image (B) had false positive painful VCFs from intraosseous herniated disc at L2 and L4 (thin arrow), and false negative painful VCF due to faint enhancement inside the thin cleft at L5 level (thick arrow). L3 (upper thick arrow) shows a thin linear hypointense cleft surrounded by linear contrast enhancement. (A) Non-enhanced T1-weighted image (TR/TE 350/8). (B) Fat-suppressed contrast-enhanced T1-weighted MR image (TR/TE 700/13).

ciency taking MR contrast media that contains gadolinium may have the potential risk of developing nephrogenic systemic fibrosis¹⁰.

In this study, we retrospectively reviewed the respective value of different MRI pulse sequences in order to detect painful osteoporotic VCFs. One important purpose of this study is to determine whether contrast-enhanced MR images are necessary in order to diagnose this condition.

Methods

We retrospectively reviewed MR images of the thoracic and lumbar spine, correlated with plain radiographs and chart records in 40 patients with osteoporotic thoracolumbar vertebral fracture(s). These 40 patients have various degree of midline, non-radiating back pain. There were 27 women and 13 men. Patients' ages ranged from 54 to 90, with an average of 74.6.

MR images were performed from several days to 14 months after the onset of acute back pain at one teaching hospital. MRI examinations were performed with a 1.5-Tesla Signa MR Scanner (General Electric Company, Mil-

waukee, WI) in 37 patients and with a 1.5-Tesla Magnetom Vision Scanner (Siemens AG, Erlangen, Germany) in three patients by using a spine-array surface coil. The following MR parameters in sagittal planes were performed in each of our patients: T1-weighted spin-echo images (TR/TE 300-650/8-22 msec, field of view: 50-100 mm, matrix: 256-1024 x 162-512), fast spin-echo T2-weighted images without fat saturation (TR/TE 2000-4250/101-139 msec, field of view: 40-100 cm, matrix: 320-1024 x 170-512), short inversion time inversion-recovery (STIR) images (TR/TE/inversion time 2500-5616/22-50/150 msec, field of view: 40-100 cm, matrix: 256-1024x154-512) and fat-suppressed contrast-enhanced T1-weighted images (TR/TE 416-700/8-22 msec, field of view: 50-100 cm, matrix: 256-1024x128-512). The contrast-enhanced MR study was performed after intravenous administration of gadolinium-diethylenetriamine pentaacetic acid (Gd-DTPA) at a dose of 0.2 mmol/kg.

Painful osteoporotic VCFs were defined as the presence of non-radiating back pain that increases with weight bearing or can be exacerbated by manual palpation or knocking of the spinous process of the involved vertebra, and having at least one of the following features on serial plain films and/or MR images: progressively decreased vertebral body height, presence of intravertebral clefts, presence of bone marrow edema¹⁻⁹.

In general, fractures with bone edema showed enhancement of vertebral bodies in the post-contrast T1-weighted MRI⁸.

Bone marrow edema was hypointense on T1-weighted images, and hyperintense on STIR images^{4,11}. On T2-weighted images without fat saturation, bone marrow edema was seen as hyperintensity or hypointensity because of the relatively high signal intensity of fatty marrow and the variable reactive fibrosis present at different time courses of the fractures⁷.

Intravertebral clefts have frequently been considered as avascular necrosis^{6,9}. Intravertebral clefts are seen as well-demarcated gaps or cavities filled with fluid or gas attenuation. The clefts were seen on T1-weighted images as hypointensity, whilst on T2-weighted and STIR images as vertebral fracture gaps or cavities filled with fluid (hyperintensity) or gas (signal void)¹². On contrast-enhanced MR images, the clefts were defined as an intravertebral non-enhanced area with surrounding enhancement⁴.

Figure 2 A 76-year-old women with painful osteoporotic vertebral compression fractures (VCFs). On plain film (A), there are sclerotic endplates (arrows) in marked collapsed vertebral bodies at T4 & T6, which are not indicated for percutaneous vertebroplasty. They simulated gas-containing clefts, and caused false positive diagnosis for painful VCFs on T1-weighted (not shown), T2-weighted (B) and STIR sequences (C). On fat suppressed contrast-enhanced T1-weighted (D), we consider they are not painful VCFs and not having a cleft inside because they do not have contrast enhancement in the bone marrow, although the signal change simulates gas-containing cleft too. This is the only one cause of false positive diagnosis for painful VCFs on the combined protocol-A. T8 vertebral body is a painful VCF with a cleft and contrast enhancement in the bone marrow (arrowhead). (A) Plain radiograph, (B) T2-weighted MR image (TR/TE 2950/108), (C) Sagittal STIR image (TR/TE/inversion time 3666/37/150), (D) Fat-suppressed contrast-enhanced T1-weighted image (TR/TE 550/11).

Palpation and knocking were performed to decide the level of painful osteoporotic VCFs prior to VP. Often patients with multiple fractures of uncertain age did not have clear localized pain upon physical examination. Therefore, plain radiographs and MR images of 40 patients were assessed blindly to the final results in order to decide the presence or absence of painful VCF features, including edema, clefts, and enhancement. We evaluated the following six sagittal protocols separately: T1-weighted images only, T2-weighted images only, STIR images only, contrast-enhanced MR

images only, the combined protocol-A (including T1-weighted images, T2-weighted images and STIR images) and the combined protocol-B (including serial plain films, T1-weighted images, T2-weighted images, STIR images, and contrast-enhanced T1-weighted MR images). Finally, we used the combined protocol-B as the gold standard for accurate diagnosis for painful VCFs. The first five protocols were compared with the combined protocol-B to assess each protocol's sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and the accuracy.

Results

A total of 510 thoracic and lumbar vertebrae of 40 patients were evaluated. A mean of 12.8 vertebral levels of the thoracic (T) and lumbar (L) spine were evaluated in each patient. Total osteoporotic vertebral fractures were found in 126 (24.7%) of 510 vertebrae. Using the combined protocol-B as the gold standard and correlating it to the clinical examination, painful osteoporotic VCFs were found in 93 (73.8%) of 126 fractures; fully healed vertebral fractures were found in 33 (26.2%) of 126 osteoporotic vertebral fractures. Single painful osteoporotic VCF was found in 14 (35%) of 40 patients, and multiple painful osteoporotic VCFs in 26 (65%) patients. On average, each patient had 2.3 painful VCFs. All patients underwent vertebroplasty. Ninety-one (97.8%) of 93 vertebral bodies with painful VCFs had bone marrow edema. Eighty (86.0%) of these 93 vertebral fractures had intravertebral clefts. Thirteen of 93 vertebral fractures had bone marrow edema without intravertebral clefts. Two of 93 vertebral fractures had intravertebral clefts without obvious bone edema. Painful osteoporotic VCFs with progressively decreased vertebral body heights on serial plain films prior to VP treatment all revealed bone marrow edema or intravertebral clefts.

The painful osteoporotic VCFs detected using each of the first five protocols are shown in

Table 1. The sensitivity, specificity, NPV, PPV and accuracy of contrast-enhanced MR images and the combined protocol-A for detecting painful osteoporotic VCFs were all above 90%.

Causes of false positives and false negatives in each of the first five protocols are presented in Table 2. Two examples are shown in Figures 1 and 2.

Discussion

Compression fractures, which cause back pain and limitations in mobility in the thoracic or lumbar spine, represent one of the most common clinical problems in elderly patients. Percutaneous vertebroplasty (VP) is beneficial in patients with painful osteoporotic VCFs for pain control and disability resolution¹³. Often, multiple osteoporotic VCFs existed in the same patient, including healed and painful VCFs. Healed VCFs do not benefit from VP, while leaving painful vertebral fractures untreated may reduce the effect of VP⁷. Many patients with multiple fractures of uncertain age did not have clear localizing pain upon physical examination; therefore, magnetic resonance imaging is important in order to determine the site of healed and painful osteoporotic VCFs^{8,14}.

Intravertebral clefts have been considered as avascular necrosis⁹. If an intravertebral cleft is found inside, we consider that to be a painful osteoporotic VCF (Figures. 1 and 2). Lane et

Table 1 Contingency table of painful osteoporotic vertebral compression fractures (VCFs) by different sequence types.

	T1-weighted	T2-weighted	STIR*	Contrast-enhanced MR	Combined Protocol-A#
TP	76	85	93	90	93
FN	17	8	0	3	0
FP	5	20	36	7	3
TN	412	397	381	410	414
Sensitivity	81.7%	91.4%	100%	96.8%	100%
Specificity	98.8%	95.2%	91.4%	98.3%	99.3%
PPV	93.8%	81.0%	72.1%	92.8%	96.9%
NPV	96.0%	98.0%	100%	99.3%	100%
Accuracy	95.7%	94.5%	92.9%	98.0%	99.4%

* STIR = Short inversion time inversion-recovery image

#Continued protocol-A= Combined protocol of sagittal T1-weighted, T2-weighted and STIR images

TP=True positive; FN=False negative; FP=False positive; TN=True negative; PPV=Positive predictive value;

NPV=Negative predictive value

Al⁹ suggested that clefts represent fracture nonunions, which occur when the bone lacks stability and/or blood supply. Oka et Al⁴ found that 24 (69%) of 35 osteoporotic fractures contained unenhanced areas on contrast-enhanced MR images and bone cement was distributed as a solid pattern within these unenhanced ar-

eas in all 24 fractures. Similar to Oka's study, we found that 80 (63.5%) of 126 osteoporotic VCFs had clefts.

Contrast-enhanced MR images demonstrate avascular necrosis or nonunion of a non-enhanced area with surrounding enhancement. Bone marrow edema of painful osteoporotic

Table 2 Causes and frequency of false positive and false negative results of detection of painful osteoporotic vertebral compression fractures (VCFs).

Pulse sequences	Causes of false negative and false positive	Frequency of painful VCFs detection
T1-weighted		
False negative	1. No obvious signal intensity change	13
	2. Thin intravertebral clefts at endplates simulating endplates sclerosis	4
False positive	1. Hypointense artifacts simulating edema	3
	2. Hypointense sclerosis from collapsed endplate stimulating intravertebral clefts	2
T2-weighted		
False negative	1. No obvious signal intensity change	8
False positive	1. Intraosseous disc herniations simulating fluid in intravertebral clefts	5
	2. Hyperintense fat island simulating fluid (n=8), or edema (n=4) in cases with true edema	12
	3. Hypointense sclerosis from collapsed endplate stimulating intravertebral clefts	3
STIR*		
False negative		0
False positive	1. Hyperintense intraosseous disc herniation simulating edema (n=6), or fluid in intravertebral clefts (n=11).	17
	2. Hypointense linear fat islands suppressed by STIR simulating intravertebral clefts	6
	3. Hyperintense artifacts simulating edema	10
	4. Hypointense sclerosis from collapsed endplates stimulating intravertebral clefts	3
Contrast-enhanced MRI		
False negative	1. No obvious contrast enhancement	2
	2. Linear contrast enhancement simulating venous structure (Fig. 1)	1
False positive	1. Contrast-enhanced intraosseous disc herniations (Fig. 1)	7
Combined protocol-A#		
False negative		0
False positive	1. Hypointense sclerosis from collapsed endplates stimulating intravertebral clefts (Fig. 2)	3

* STIR = Short inversion time inversion-recovery image

#Combined protocol-A= Combined protocol of sagittal T1-weighted, T2-weighted and STIR images

VCFs with accompanying enhancement was easily detected on contrast-enhanced MR images (Figure 2). The sensitivity, specificity, PPV, NPV, and accuracy for detection of painful osteoporotic VCFs on contrast-enhanced MR images were all more than 90% in our study. Therefore, the contrast-enhanced MR image is a very effective tool for detecting painful osteoporotic VCFs prior to VP. However, there are disadvantages of using gadolinium-based MR contrast media followed by non-contrasted MR images: (a) it requires more time to perform; (b) it is more expensive; (c) the patient with impaired renal function is at risk of developing nephrogenic systemic fibrosis¹⁰.

There are false positive and false negative results that occur when detecting painful VCFs in individual pulse sequences from different causes (Table 2). With a combination of non-enhancement techniques, the combined protocol-A had high sensitivity, specificity, PPV, NPV, and accuracy for the detection of painful osteoporotic VCFs (all >90%) (Table 1). The vast majority of false positive diagnoses that resulted in a lower PPV for the detection of painful osteoporotic VCFs on T2-weighted images or STIR images can be improved with the combined protocol-A. In addition, all false negative diagnoses on T1-weighted images that resulted in lower sensitivity can be improved with the combined protocol-A. A false positive of the combined protocol-A was found on one occasion only: when collapsed endplates simulated a gas-filled cleft (Figure 2). This was clarified by careful review and comparison between plain films and MR images. The combined protocol-A had no false negatives, nor did any occur for the STIR sequence. Therefore, a combined protocol-A can be used alone without taking subsequent contrast-enhanced MR images for the detection of painful osteoporotic VCFs before VP.

Conclusions

In summary, the combined protocol-A including T1-weighted, T2-weighted and STIR images had similar high sensitivity, specificity, PPV, NPV, and accuracy (all >90%) as compared to contrast-enhanced MR images for the detection of painful osteoporotic VCFs. In addition, use of the combined protocol-A provided a faster, cheaper, and safer technique without requiring intravenous administration of

gadolinium-based MR contrast medium. We suggest that contrast-enhanced MR images can be omitted in the detection of painful osteoporotic VCFs prior to VP, unless there are conditions where contrast-enhanced MR is needed for making a differential diagnosis.

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