

Magnetic Resonance Imaging Characteristics of Benign and Malignant Vertebral Fractures

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Background: Attempts to differentiate benign and malignant vertebral fractures may be difficult, particularly when there is no obvious evidence of malignancy. Since early diagnosis and appropriate management of malignant vertebral fractures are important, a reliable imaging modality is required.

Methods: From January 1996 to December 2002, 48 patients with malignant vertebral fractures and 50 patients with benign processes were studied. All patients underwent conventional magnetic resonance imaging (MRI) scanning for acute vertebral compression fractures within 2 months of presenting with the complaint. Seven MRI characteristics were used as criteria, including signal intensity, gadolinium enhancement, epidural compression, multiple compression fractures, associated paraspinal soft tissue mass, pedicle involvement, and posterior element involvement. The predictive value of each MRI characteristic for distinguishing malignant from benign osteoporotic vertebral fractures was tested by statistical analysis.

Results: Lesions with negative gadolinium enhancement were favored as benign fractures. A uniform signal change in multiple involved vertebra lesions, round, smooth margins with marked epidural compression, a paraspinal soft tissue mass, and pedicle and posterior element involvement were probable malignant characteristics. Among them an associated paraspinal soft tissue mass was found to be significant in predicting the probability of malignancy.

Conclusions: Certain MRI characteristics allow early differentiation of benign and malignant vertebral fractures.

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Key words: vertebral fractures, magnetic resonance imaging, osteoporosis, metastasis.

Attempts to differentiate benign and malignant vertebral fractures may be difficult, particularly when there is no obvious evidence of malignancy on plain radiography. This is especially true in elderly patients, who are predisposed to senile osteoporosis and malignant disease. Symptoms and signs of both

types of fracture may be nonspecific and the only complaint may be back pain.

Increasing experience with magnetic resonance imaging (MRI) of spinal disorders has revealed the potential usefulness of this technique in distinguishing benign from malignant fractures.⁽¹⁻¹²⁾ However,

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the time from injury or the time from presenting with the complaint to performing MRI scans ranged widely in the majority of studies. The role of MRI in the acute phase of vertebral fractures has not been widely and specifically studied although the acute phase of vertebral fractures is the most critical period for defining fracture management. In addition, the use of MRI diagnostic criteria in the early differentiation between benign and malignant vertebral fractures remains uncertain. Moreover, accurate differentiation between the two fractures remains a difficult problem even using newer technique such as diffusion-weighted imaging.^(13,14)

Since the management of malignant spine fractures differs from that for benign spine fractures, simple and reliable diagnostic criteria based on image studies for early diagnosis is needed. The purpose of this study is to analyze and determine which conventional MRI parameters are useful for the early differentiation between benign and malignant vertebral fractures.

METHODS

From January 1996 to December 2002, we retrospectively evaluated hospital charts and diagnostic studies of 98 patients. All patients had undergone conventional MRI scans for acute vertebral compression fractures within 2 months from the time of presenting with the complaint. Of the patients, 48 were men and 50 were women, aged between 36 to 85 years (mean, 63.3 years). Pain associated with acute vertebral compression fractures should have involved the segment of the back with the vertebral fracture for less than 2 months after a trivial injury or symptom onset. The 2 month cutoff was chosen because, in our clinical experience, some cases of osteoporotic vertebral fractures remain painful even after conventional conservative treatment. Furthermore, it is often during these periods that MRI studies are recommended for these patients to define the cause of the vertebral fractures and to select the appropriate treatment.

A thorough evaluation of all patients was performed, which included evaluation of past medical history with special attention to malignant disease, laboratory tests, clinical examination, and plain radiographs of the thoracic and lumbar spine. Patients with any sign of infection or with proven spinal

infection were excluded. All patients underwent MRI for vertebral lesions with gadolinium-diethylene triamine pentaacetic acid (Gd-DTPA) contrast-enhancement. Conventional MRI examinations were conducted with a 1.5-Tesla Signa Scanner (General Electric Medical Systems, Milwaukee, WI, USA) using standard spine imaging techniques. T1- and T2-weighted images in the sagittal and axial planes were obtained in each patient.

Fifty patients with benign and 48 with malignant compression fractures were enrolled in the study group and assessed retrospectively. Of the 50 patients with a diagnosis of osteoporotic vertebral fractures, 26 underwent surgery because of intractable pain or neurologic deficit, and thus the diagnosis was primarily based on pathological results following surgery. Two other patients were diagnosed with osteoporotic vertebral fractures based on pathologic results following needle biopsy. In the remaining 22 patients, diagnosis was based on follow-up (minimum 12 months) radiographic examinations in conjunction with clinical histories. When the appearance of the follow-up radiographic studies showed no further progression of the fracture and the symptoms improved during the follow-up period, benign processes were considered the most likely causes of the fractures.

All of the 48 patients with malignant vertebral fractures were diagnosed primarily based on pathological results following surgery. The reasons for surgical intervention were intractable pain and neurologic deficit. Eighteen of these patients had a past history of malignant disease and metastasis to the vertebrae was confirmed by the pathologic data (lung carcinoma [n=3], colon carcinoma [n=4], hepatoma [n=5], nasopharyngeal carcinoma [n=2], breast carcinoma [n=2], tongue carcinoma [n=1], and lymphoma [n=1]). The other thirty patients had no past history of malignant disease. Back pain was the first presenting symptom. These patients were eventually diagnosed to have lung carcinoma [n=6], hepatoma [n=6], renal cell carcinoma [n=3], prostate carcinoma [n=2], thyroid carcinoma [n=1], multiple myeloma or plasmacytoma [n=3], metastatic adenocarcinoma [n=6], and poorly differentiated carcinoma [n=3].

A review of the literature and our own clinical experience was used to choose MRI characteristics to evaluate the vertebral lesions.^(1,5,7,8) The 7 MRI characteristics chosen included signal intensity, gadolini-

um enhancement, epidural compression, multiple compression fractures, associated paraspinal soft tissue mass, pedicle involvement, and posterior element involvement. Lesion enhancement with gadolinium on the T1 image was assessed between the lesion and the adjacent bone marrow.

The appearance of each MRI characteristic on images was determined and recorded. Statistical analysis was performed using the statistical software package SAS Version 8e (SAS Institute Inc. Cary, NC, USA). The possible factors associated with confirmation of tumor type were analyzed using the Chi-square test, Fisher's exact test, simple logistic regression and full model multiple logistic regression. The level of statistical significance was set at $p < 0.05$.

RESULTS

MRI characteristics from images of benign and malignant vertebral lesions are summarized in Table 1 and Table 2. Gadolinium enhancement, epidural compression, paraspinal soft tissue mass, pedicle involvement, and posterior element involvement were significantly useful in the early differentiation of benign from malignant vertebral fractures by Chi-square test or Fisher's exact test. The odds ratio of malignancy by unifactorial logistic regression analysis also revealed these characteristics had significant predictive value. Among these characteristics, paraspinal soft tissue mass was significant in predicting the probability of malignancy by multifactorial logistic regression analysis.

Signal Intensity

Thirty-four benign (68.0%) and 33 malignant (68.8%) vertebral lesions had simultaneously decreased signal intensity on T1-weighted images and increased signal intensity on T2-weighted images ($p = 0.94$). The appearance of other vertebral lesions varied. In the benign group, 10 lesions had low signal on T1 and iso-signal on T2 images, 4 had iso-signal on both T1 and T2 images, and 2 were iso-signal on T1 and low signal on T2 images. In the malignant group, 9 lesions had low signal on T1 and iso-signal on T2 images, 2 had iso-signal on both T1 and T2 images, 2 had low signal on T1 and T2 images, and 2 had increased signal on T1 and T2 images.

Gadolinium enhancement

Forty-two benign (84.0%) and all 48 malignant (100%) cases had gadolinium enhancement when compared with the pre-enhanced T1-images ($p = 0.006$). The 8 fracture lesions without gadolinium enhancement were all benign.

Epidural compression

Thirty-four benign (68.0%) and 41 malignant (85.4%) cases had a posterior bulging mass with epidural compression ($p = 0.042$). A round, smooth margin with marked epidural compression was likely to occur in malignant lesions (Fig. 1A). In contrast, retropulsion of a bony fragment of the posterosuperior angle with epidural compression was likely to occur in benign osteoporotic fractures (Fig. 1B).

Multiple level involvement

Twenty-six benign cases (52.0%) and 33 malignant cases (68.8%) involved more than one vertebral body ($p = 0.090$). Different signal intensities in the involved vertebral lesions on T1- and T2-images were found in benign cases. On the other hand, signal intensities of the involved vertebral lesions on the T1- and T2-images in malignant cases were the same.

Paraspinal soft tissue mass

Four benign cases (8.0%) had rim-shaped soft tissue lesions in the paraspinal area surrounding the collapsed vertebrae, observed only in gadolinium enhanced images (Fig. 2A). In contrast, an irregular-shaped paraspinal soft tissue mass was observed on images (Fig. 2B) in 46 malignant cases (95.8%). In all of these case, the soft tissue mass were enhanced by Gd-DTPA. The appearance of a paraspinal soft tissue mass was statistically significant in malignant fractures ($p < 0.001$).

Pedicle involvement

Pedicle involvement was seen with 6 benign cases (12.0%) only after Gd-DTPA enhancement. Of the malignant cases, 45 (93.8%) showed a MR signal change and tumor mass around the pedicle before enhancement of the images. The difference in pedicle involvement between benign and malignant fractures was statistically significant ($p < 0.001$).

Posterior element involvement

Of the benign cases, 2 (4.0%) showed posterior

Table 1. Statistical Analysis of Benign and Malignant Compression Fractures

MRI Characteristics	Final Diagnosis		Statistical Analysis <i>p</i> *
	Osteoporosis (n=50)	Metastasis (n=48)	
Signal T1 low, T2 high	34	33	.9364
Gadolinium enhancement	42	48	.0058
Epidural compression	34	41	.0420
Multiple levels	26	33	.0904
Paraspinal soft tissue mass	4	46	< .0001
Pedicle involvement	6	45	< .0001
Posterior element expansion	2	40	< .0001

Abbreviation: MRI: magnetic resonance imaging.

* by Chi-square test or Fisher's exact test.

Table 2. The Odds Ratio of Malignancy With Different Factors

Factor	Unifactorial			Multifactorial (full model)		
	Odds Ratio	95% CI of OR	<i>p</i> *	Odds Ratio	95% CI of OR	<i>p</i> *
T1 low , T2 high						
Yes	1.04	0.44 ~ 2.43	0.9364	0.93	0.10 ~ 9.12	0.9508
No (ref)						
Enhancement						
Yes	19.40	1.09 ~ 346.2	0.0058	25.82	0.80 ~ 829.6	0.0663
No (ref)						
Soft tissue mass						
Yes	264.5	46.15 ~ >999	< .0001	168.9	3.40 ~ >999	0.0101
No (ref)						
Epidural compression						
Yes	2.76	1.02 ~ 7.47	0.0465	3.40	0.26 ~ 44.7	0.3517
No (ref)						
Multiple levels						
Yes	2.03	0.89 ~ 4.63	0.0923	2.66	0.26 ~ 27.42	0.4113
No (ref)						
Posterior element						
Yes	120.0	24.10 ~ 597.5	< .0001	0.89	0.02 ~ 54.06	0.9548
No (ref)						
Pedicle involvement						
Yes	110.0	25.88 ~ 467.5	< .0001	3.15	0.07 ~ 140.6	0.5536
No (ref)						

Abbreviations: CI: confidence intervals; OD: odds ratio; ref: reference

* by logistic regression.

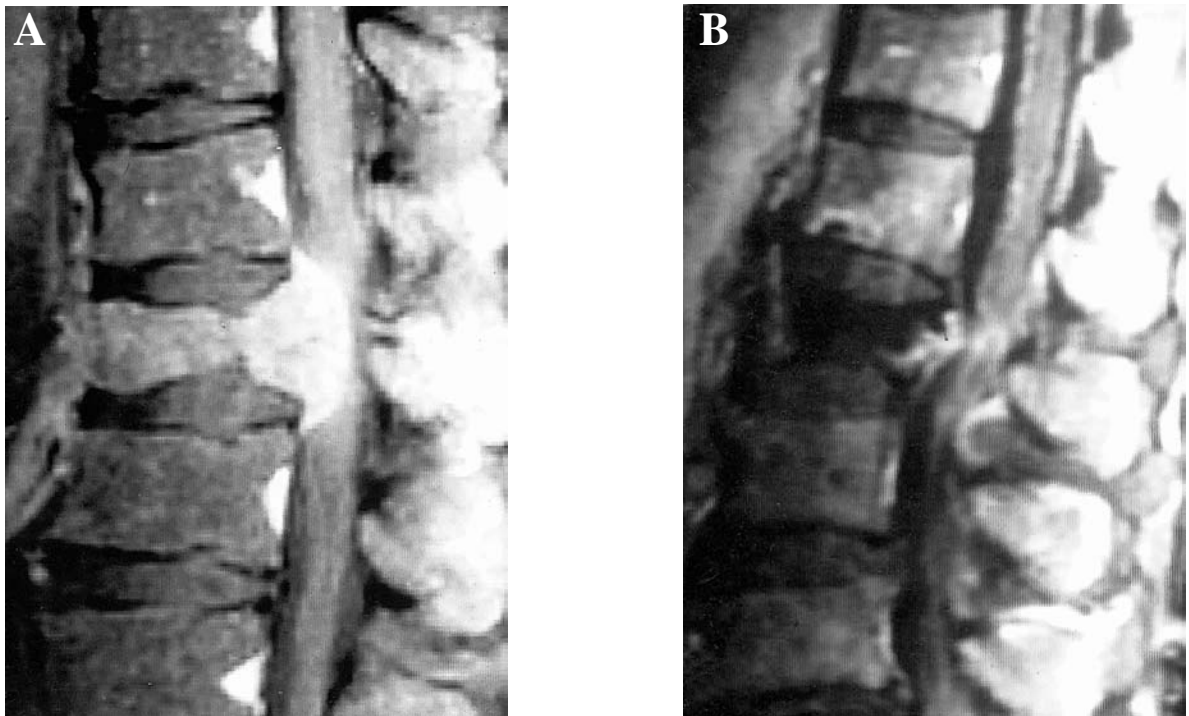


Fig. 1 (A) Contrast-enhanced sagittal magnetic resonance imaging, showing a round, smooth posterior margin with marked epidural compression in a patient with malignant compression fracture. (B) Retropulsion of a bony fragment of the posterosuperior angle with epidural compression is shown in a benign fracture.

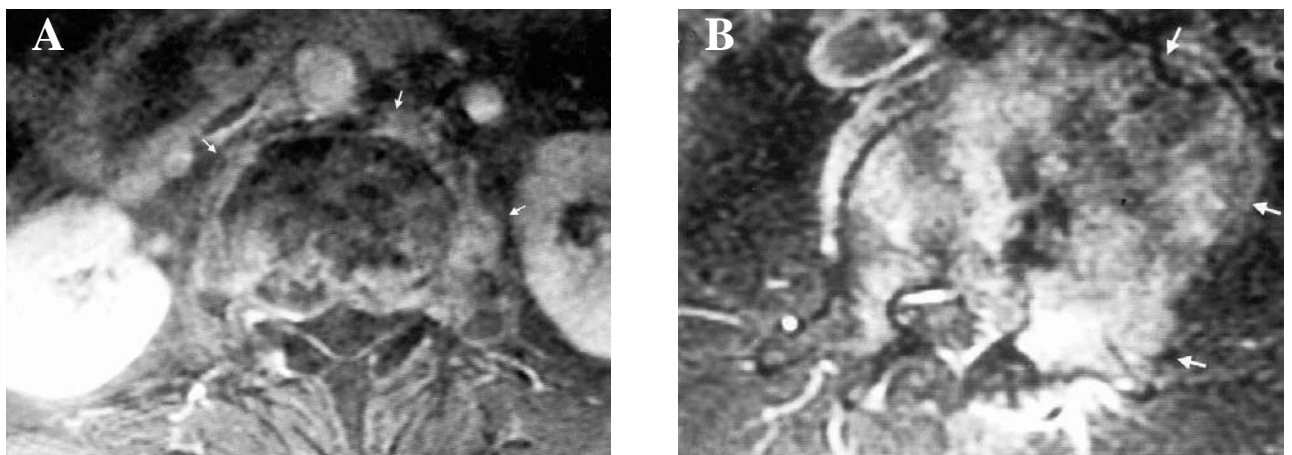


Fig. 2 (A) Axial postgadolinium magnetic resonance imaging showed rim-shaped soft tissue lesions (arrow) in the paraspinal area surrounding the benign collapsed vertebrae. (B) A malignant lesion shows formation of an irregular-shaped paraspinal soft tissue mass (arrow).

element involvement. Of the malignant cases, 40 (83.3%) showed bony destruction around the lamina and spinous process. The appearance of posterior element involvement after Gd-DTPA enhancement was statistically significant in malignant fractures ($p < 0.001$).

DISCUSSION

The differential diagnosis between benign and malignant causes of vertebral compression fracture is a common clinical problem. The limitations of plain radiograph, bone isotope scanning, myelography, and computed tomography in the diagnosis of benign and malignant compression fractures have been well documented.⁽¹⁵⁻¹⁸⁾ Radionuclide bone scanning is sensitive but not specific. Myelography is useful for visualizing cord compression but is associated with a significant risk of neurologic deterioration.⁽¹⁹⁾ Since early diagnosis and management of malignant fractures are important to prevent further neurological compromise, a reliable and noninvasive imaging modality is needed.

It has been reported that both malignant and acute benign fractures may give rise the pattern of low T1 and high T2 signal on MRI.^(2,11,20) This is attributed to increased focal water content resulting from hemorrhage and edema. After the acute stage, hematoma and edema decrease, resulting in a low to intermediate signal intensity on T2-weighted images. However, in malignant fractures, the infiltrated abnormal tissues and associated reactive response continue to show the low T1 and high T2 signal patterns.⁽⁷⁾ Although this characteristic is reported to be helpful in differentiating between benign and malignant fractures, we found that this is not always the case as signal intensity changes can be similar in both malignant and benign cases, especially during the early stages.

Contrast-enhanced MRI is commonly used in the evaluation of tumors. Rupp et al. had reported that use of gadolinium contrast did not appear to be useful in the differentiation of osteoporotic from tumor compression fractures.⁽⁷⁾ On the contrary, An et al. reported that contrast enhancement was very sensitive in detecting malignant lesions, with a sensitivity of 100%, but its specificity could be compromised by misinterpretation of benign lesions as malignant especially during the healing process of benign fractures.⁽¹⁾ Our results agree with An et al. In

our study, 42 benign (84.0%) and all 48 malignant (100%) cases had gadolinium enhancement. On the contrary, lesions with negative enhancement are favored as benign fractures.

Of the malignant cases in our study, 41 (85.4%) had a moderate to severe posterior bulging mass with epidural compression. We did not calculate the size of the posterior bulging fragment or the degree of spinal canal encroachment. Generally, an epidural mass of a round, smooth margin of was more likely to occur in malignant lesions. On the contrary, retropulsion of a bony fragment of the posterosuperior angle with epidural impingement was likely to occur in benign fractures.

Metastatic disease and osteoporosis may have diffuse involvement and present with multiple lesions of the spine. Although this characteristic did not appear to be useful in differentiating benign and malignant fractures in the present study, the signal pattern of the involved vertebrae was different in these two fractures. In the benign cases, the signal intensity was different in the different involved levels in each patient. On the other hand, the signal intensity was the same in the involved vertebral lesions in the malignant cases. It is possible that patients with osteoporosis may have had vertebral compression fractures due to trivial injuries affecting different levels at different times, thus explaining the different signal intensities of the involved vertebral fractures. Otherwise, metastasis and infiltration of the tumor cells would involve different levels of vertebrae, and the associated reactive response would continue, even at the different stages.

Several studies have mentioned that the presence of an associated paraspinal soft tissue mass is indicative of malignancy.^(6,7,16) This was confirmed in our study. We found that most malignant cases had an irregularly shaped paraspinal soft tissue mass on MRI.

The early detection of spinal metastasis by plain radiograph is difficult as most tumors are not apparent on plain film until more than 30% of the vertebral body has been destroyed. However, MRI can detect early vertebral and pedicle destruction. In our study, 6 benign cases (12.0%) had pedicle involvement, but this could be seen only after Gd-DTPA enhancement. On the other hand, 45 malignant cases (93.8%) had pedicle destruction with expansile soft tissue. This finding is significant in predicting malig-

nancy.

Rupp et al. concluded that posterior vertebral expansion did not help in the differentiation of osteoporotic from tumor compression fractures.⁽⁷⁾ This is in contrast to our results. Most metastatic tumors of the spine spread to the vertebral body first and then later invade the pedicles and posterior elements. However, benign compression fractures are often confined to the anterior element. This characteristic is significant in the differentiation of benign from malignant vertebral fractures.

In conclusion, certain MRI characteristics allow early differentiation of benign and malignant vertebral fractures. Negative gadolinium-DTPA enhancement of the vertebral fracture is favored as a benign lesion. Uniform signal change in multiple vertebral lesions, a round, smooth margin with marked epidural compression, a paraspinal soft tissue mass, and pedicle and posterior element involvement are likely to lead to a diagnosis of malignant fracture. Of these probable malignant characteristics, an associated paraspinal soft tissue mass was found to be significant in predicting the probability of malignancy.

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核磁共振造影術在良性與惡性脊椎骨折之影像特性

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背景： 區分早期骨質疏鬆造成的良性或惡性腫瘤轉移所造成之脊椎骨折，在臨床治療上相當重要。本研究的目的是從分析核磁共振造影術影像的各種不同表現，找出可供早期區分此兩種骨折之影像特徵。

方法： 從1996年至2002年，98位有脊椎壓迫性骨折的病人，接受傳統核磁共振攝影術的檢查。大部分的病人依病理組織報告，其餘則依臨床追蹤來定其最終之診斷。7個不同的影像特徵：同時具有T1影像訊號減弱及T2訊號增強現象、顯影劑注射後訊號增強、多節椎體骨折、脊髓硬膜被擠壓、椎體旁軟組織腫瘤形成、椎弓根 (pedicle) 破壞、或脊椎後部位構造破壞等，被選擇來獨立分析每個病人的核磁共振影像，並用統計分析方法，決定其是否可以用來早期區分良性或惡性脊椎骨折。

結果： 在顯影劑注射後，若沒有訊號增強的情形，則較可能診斷為良性脊椎骨折。而惡性脊椎轉移性骨折，則易有表現相同訊號之多節骨折、椎體旁軟組織腫瘤形成、椎弓根破壞、或脊椎後部位構造破壞的情形。

結論： 在良性與惡性脊椎骨折的病患，核磁共振攝影的影像會表現出不同的特徵。應用核磁共振攝影檢查及其影像特徵的判讀，可以做為早期區分良性或惡性脊椎骨折的方法。

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關鍵字： 脊椎骨折，核磁共振攝影，骨質疏鬆，惡性腫瘤轉移。