Available online at www.sciencedirect.com

ScienceDirect

Journal of the Chinese Medical Association 78 (2015) 714–718

www.jcma-online.com

Original Article

Determination of the painful level in osteoporotic vertebral fractures—Retrospective comparison between plain film, bone scan, and magnetic resonance imaging

Hsi-Hsien Lin [a,b], Po-Hsin Chou [a,b], Shih-Tien Wang [a,b], Jung-Kuang Yu [a,b], Ming-Chau Chang [a,b,*], Chien-Lin Liu [a,b]

[a] *Department of Orthopedics and Traumatology, Taipei Veterans General Hospital, Taipei, Taiwan, ROC*
[b] *National Yang-Ming University School of Medicine, Taiwan, ROC*

Received October 6, 2014; accepted February 12, 2015

Abstract

Background: Determining the actual painful vertebral level is difficult when evaluating osteoporotic vertebral fracture, especially when there are acute and chronic fractures simultaneously. In this study, we retrospectively evaluated and compared the findings between plain film, bone scan, and magnetic resonance imaging (MRI) in the diagnosis of new fracture in osteoporotic vertebral fractures.
Methods: This is a retrospective clinical study of patients who were diagnosed with osteoporotic vertebral fractures using plain film, bone scan, and MRI within a 1-month interval between February 2008 and December 2012. The findings in plain film, the extent of increased uptake in bone scan, and signal change in MRI were compared to evaluate the actual level of pain. All patients received percutaneous vertebroplasty according to MR finding. Pain scores (visual analog scale) of the study patients were compared prior to and after the procedure.
Results: A total of 52 patients with a mean age of 79.1 years (range 59–92 years) were enrolled in this study, and were treated by vertebroplasty confirmed by MRI. It was observed that patient pain score (visual analog scale) improved from 7.6 to 2.8. Plain film examination revealed 79 vertebrae that were suspected to be compression fractures. Among the suspected vertebrae, 62 showed increased uptake in bone scan, and MRI showed bony edema change in 58 vertebrae. The consistency between bone scan and MRI was 96.9% in patients with single-level suspected fracture on plain film. There was moderate agreement (kappa was 0.56) in patients where multiple levels were noted. Fifteen vertebrae with vacuum cleft sign on plain film showed total concordance in both bone scan and MRI.
Conclusion: For patients with single-level compression fracture, the painful level in osteoporotic vertebral fractures can be determined by plain film and bone scan testing. Vacuum cleft sign noted on plain film may be enough to localize the level of pain. However, MRI testing is further needed in multiple osteoporotic vertebral fracture patients.
Copyright © 2015 Elsevier Taiwan LLC and the Chinese Medical Association. All rights reserved.

Keywords: bone scan; magnetic resonance imaging; osteoporosis; vertebral compression fracture

1. Introduction

As the mean age of the population continues to increase, the incidence and risk of vertebral compression fracture due to osteoporosis have recently manifested a rising trend. For such osteoporotic vertebral compression fracture patients, it is important to accurately determine the symptomatic vertebra prior to establishing treatment levels.

Conflicts of interest: The authors declare that there are no conflicts of interest related to the subject matter or materials discussed in this article.

* Corresponding author. Dr. Ming-Chau Chang, Department of Orthopedics and Traumatology, Taipei Veterans General Hospital, 201, Section 2, Shih-Pai Road, Taipei 112, Taiwan, ROC.
E-mail address: bdmcchang@gmail.com (M.-C. Chang).

http://dx.doi.org/10.1016/j.jcma.2015.06.015
1726-4901/Copyright © 2015 Elsevier Taiwan LLC and the Chinese Medical Association. All rights reserved.

However, it is difficult to find the painful level using only plain X-rays in those patients whose time of fracture onset and site of pain are unclear. It is also not easy to perform a physical examination on elderly patients. Increased activity revealed by bone scan is highly predictive of positive clinical response after surgical treatment.[1] The diagnostic benefits of magnetic resonance imaging (MRI) include the capacity to identify the correct location of injury and also detect concomitant diseases.[2] In this study, we evaluated the findings of plain film examination and the efficacy of bone scan and MRI to diagnose a painful fracture, which is an acute fracture or chronic nonunion fracture, in elderly patients with osteoporotic vertebral compression fracture.

2. Methods

Between February 2008 and December 2012, 52 patients diagnosed with osteoporotic vertebral fracture who received vertebroplasty were retrospectively reviewed after institutional review board approval. All patients underwent a plain film, bone scan, and MRI testing within a 2-month period. The mean age of the patients was 79.1 years (range 59–92 years), and there were 20 male and 32 female patients. The presence of vertebral body compression fracture was assessed by plain X-ray and bone scan, and MRI was thereafter performed to decide the level of percutaneous vertebroplasty.

The decreased body height, wedge or biconcave shape, and vacuum defect in plain film were suspected to be involved with the painful level. The vacuum defect was considered to be associated with nonunion related to the formation of pseudoarthrosis in these vertebrae. The suspected lesions were divided into three groups: (1) single-vertebral-body group, (2) two-vertebral-body group, and (3) more-than-three-vertebral-body group. The intensity on the bone scan increased more than the hot uptake by the anterior superior iliac spine and the posterior superior iliac spine, leading to a diagnosis of increased uptake lesions.

MRI was then used to confirm the painful level by distinguishing between painful and painless fractures according to the appearance of bone marrow edema and hemorrhagic fluid. Levels with low intensity on the T1-weighted image and high intensity on the T2-weighted image were considered to be the painful levels. Malignant lesions and cemented vertebral bodies with or without a signal change were excluded. All patients underwent percutaneous vertebroplasty by the same surgeon, each with an MRI-confirmed level of signal change. Focusing on the pain relief, patients were asked to provide a value for pain intensity using a visual analog scale, ranging from 0 to 10, prior to and after the procedure.

Due to the postvertebroplasty appearance of cold defect on bone scan,[3] cemented vertebral bodies were assumed not to rise to the painful level and were excluded even if similar signal changes were evident on MRI.[4]

The uptake levels on bone scan in the three groups were then compared and evaluated depending on the change of signal intensity on MRI. For the statistical analysis, paired Student t tests were performed for pain score, and $p < 0.05$ was considered to be significant. Agreement and kappa statistics were used for concordance between plain film, bone scan, and MRI.

3. Results

Among the 52 patients who underwent plain X-ray, bone scan, and MRI, 79 vertebrae showed characteristic findings of vertebral compression fractures on plain film, and vacuum defect was identified in 15 vertebrae. On bone scan, increased uptake was noted in 59 vertebrae, and 45 were confirmed to have a painful fracture by MRI and received vertebroplasty under local anesthesia.

A total of 32 patients had single-level suspected vertebral compression on plain film. Among the 32 vertebral bodies, 31 were determined by bone scan to have an increased uptake lesion and 30 vertebral bodies (96.7%) were determined to have a painful fracture by MRI. The agreement between the results of bone scan and MRI was 96.9% in patients with a single-level suspected vertebral fracture on plain film.

In patients with more than two levels of suspected fractures on plain film, increased uptake on bone scan was noted for 28 out of 47 vertebrae (59.5%). Additionally, 15 vertebrae were confirmed to have a painful fracture by MRI. One of the cases is presented in Fig. 1. The agreement between bone scan and MRI was 76.6%, and the kappa value was 0.56. In multiple-level patients, the concordance percentage of plain film and MRI was 31.9% and that of bone scan and MRI was 53.5% (Table 1).

Intravertebral air, known as vacuum cleft sign or pseudoarthrosis, and considered nonunion, was identified in 15 vertebral bodies. Altogether, all 15 vertebral bodies (100%) showed an increased uptake on bone scan. All of these 15 vertebral bodies were determined as painful level by MRI confirmed low intensity on T1-weighted image and high intensity on the T2-weighted image, suggesting fluid occupation of the cleft (Fig. 2).

The average pain score before vertebroplasty was 7.6. By MRI determination in this study, the pain score improved to 2.8 immediately after the procedure, with statistical significance (Table 2).

4. Discussion

Localizing the level of pain is difficult to achieve in treating patients with multiple osteoporotic fractures of uncertain age. Besides physical examination, preoperative evaluation including plain X-ray, computed tomography, and MRI may all be needed to achieve the therapeutic effect of percutaneous vertebroplasty.[5] Bone scanning has been reported to be reliable in treatment planning and predicting pain relief after kyphoplasty.[6] It is also valuable for detection and assessment of vertebral fracture age in patients with severe osteoporosis.[7] However, bone scan imaging may reveal increased activity for up to 2 years after fracture. Furthermore, there is a lag period of $\geq$ 1 week following collapse in elderly patients.[8] The overall positivity of the bone scan in detection of levels that

(A)

(B)

Fig. 1. (A) Multiple compression fractures on plain film: T9 cleft sign and T12 postvertebroplasty. (B) T9 new fracture with hot uptake on bone scan.

were treated subsequently with vertebroplasty was 78.3%.[9] In our study, there was a 96.7% bone scan concurrence consistent with the painful level determined by MRI in single-level suspected on plain film. However, in multiple-level patients, 53.5% showed increased uptakes on bone scan were diagnosed with painful level by MRI.

Table 1
Levels on plain film that were positive on bone scan and MRI in patients with single versus multiple fractures.

Plain film (No. of vertebra)	Bone scan	MRI	Agreement
Single level (32)	31 (96.8)	30 (93.7)	96.9
Multiple levels (47)	28 (59.5)	15 (31.9)	76.6

Data are presented as % or *n* (%).
MRI = magnetic resonance imaging.

MRI has been proved to be useful in discriminating benign and malignant fractures, demonstrating the correct location of injury, and detecting concomitant diseases.[2] In osteoporotic vertebral fractures, it could accurately distinguish between fresh and old vertebral compression fractures,[10] and several characteristics were described depending on the age of fracture.[11] In general, the geographic patterns that exhibited low intensity on the T1-weighted image and high intensity on the T2-weighted image were new fractures due to the presence of an intervertebral edema or hemorrhagic fluid.[12] On T2-weighted image, linear low band-like signal structures

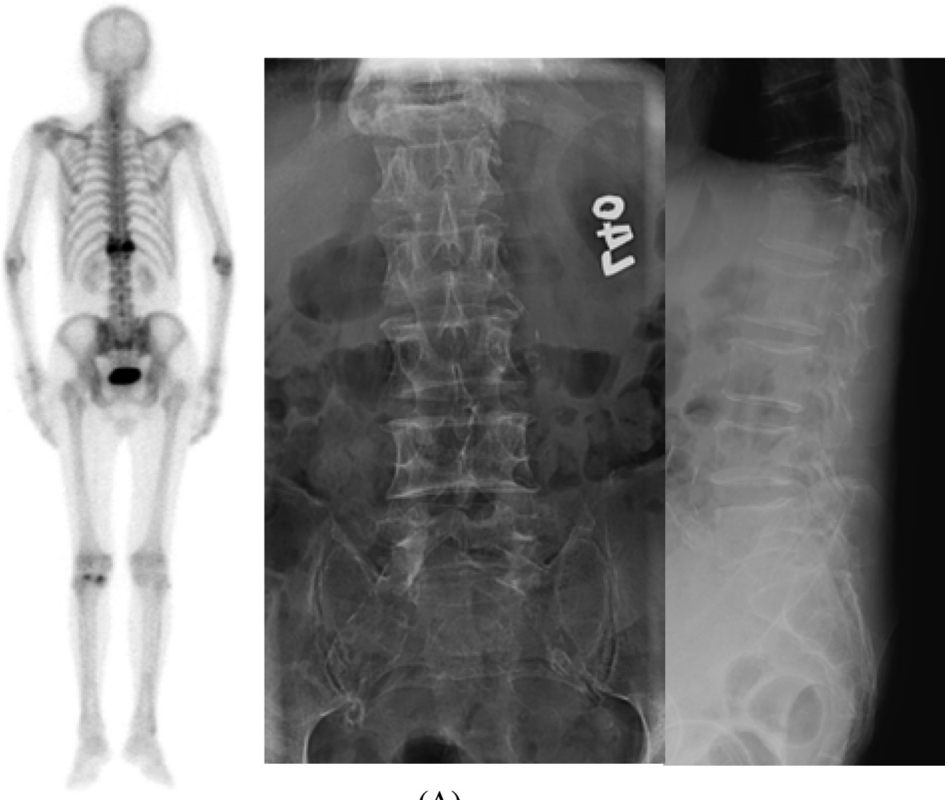

Fig. 2. (A) L1 cleft sign on plain film and hot uptake on bone scan. (B) Low density on T1 and high density on T2.

Table 2
Pain score (VAS) before and after vertebroplasty determined by MRI.

Patients (*n*)	Pre-VP	Postop	*p*
Single level (32)	7.8	2.5	<0.001
Multiple levels (20)	7.3	3.3	<0.001
Overall (52)	7.6	2.8	<0.001

MRI = magnetic resonance imaging; VAS = visual analog scale; VP = vertebroplasty.

correspond with the callus woven bone tissues.[13] Using the MR images, occult injuries including contusions or microtrabecular fractures (which may be the pain source in the acute stage) could also be identified.[14] The abnormal signal gradually reverts to normal in 2−4 months, and chronic benign osteoporotic fractures usually show normal signal intensity of the vertebral body on both T1- and T2-weighted images.

Three fracture patterns—wedge, crush, and biconcave—have been described in the osteoporotic spine.[15] Intravertebral air, also known as vacuum cleft sign or pseudoarthrosis, was recognized as an early microfracture that was presumed to be an insufficiency fracture or a vertebral bone avascular necrosis. The radiolucent area is more visible on the lateral-view plain X-ray. Changing position could lead to fluid replacement of the cleft and a signal change on sequential T2-weighted images.[16] Basically, both induced osteoblastic activity and showed increased uptakes on bone scan. It is difficult to diagnose osteoporotic vertebral fractures on plain radiograph, especially in patients without deformity or trauma.[17] In our study, vacuum cleft sign noted on plain radiograph showed 100% concordance (15/15) with increased uptakes on bone scan and findings of new fractures on MRI.

It is easier to diagnose single-level osteoporotic vertebral fracture because of the recent onset of pain, clearer traumatic event, more indicative physical examination, and improved bone mineral quality. The rate of new vertebral fractures confirmed by MRI according to 1 level increased uptake in bone scan was 96%.[12] The possibility of confirming the increased uptake lesion on bone scan as a new fracture by MRI is reduced when more vertebral bodies are involved. In this study, we tried to identify the uptake intensity on bone scan, and the concordance was high in cases of single-level osteoporotic vertebral fractures and hot uptakes. However, in multiple osteoporotic vertebral fractures, more careful interpretation regarding increased uptake lesions is needed.

This study had some limitations. First, this is a retrospective clinical study. Second, there was only one method of management, which was assessed without randomization or blinding. Finally, the procedure of vertebroplasty and the interpretation of image findings were performed by a single senior surgeon.

In conclusion, the painful level in a single-level compression fracture can be determined by plain film and bone scan. Vacuum cleft sign noted on plain film may be enough to localize the painful level. However, in addition to these, MRI is needed in multiple osteoporotic vertebral fracture patients.

References

1. Maynard AS, Jensen ME, Schweickert PA, Marx WF, Short JG, Kallmes DF. Value of bone scan imaging in predicting pain relief from percutaneous vertebroplasty in osteoporotic vertebral fractures. *AJNR Am J Neuroradiol* 2000;**21**:1807−12.
2. Spiegl UJ, Beisse R, Hauck S, Grillhosl A, Buhren V. Value of MRI imaging prior to a kyphoplasty for osteoporotic insufficiency fractures. *Eur Spine J* 2009;**18**:1287−92.
3. Lavely WC, Malhotra AD, Ziessman HA, Murphy KP. Cold defect on bone scan in a vertebral body after percutaneous vertebroplasty. *Skeletal Radiol* 2006;**35**:946−8.
4. Chen LH, Hsieh MK, Liao JC, Lai PL, Niu CC, Fu TS, et al. Repeated percutaneous vertebroplasty for refracture of cemented vertebrae. *Arch Orthop Trauma Surg* 2011;**131**:927−33.
5. Franc J, Lehmann P, Saliou G, Monet P, Kocheida EM, Daguet E, et al. Vertebroplasty: 10 years clinical and radiological follow-up. *J Neuroradiol* 2010;**37**:211−9.
6. Karam M, Lavelle WF, Cheney R. The role of bone scintigraphy in treatment planning, and predicting pain relief after kyphoplasty. *Nucl Med Commun* 2008;**29**:247−53.
7. Kucukalic-Selimovic E, Begic A. Value of bone scintigraphy for detection and ageing of vertebral fractures in patients with severe osteoporosis and correlation between bone scintigraphy and mineral bone density. *Med Arh* 2004;**58**:343−4.
8. Matin P. The appearance of bone scans following fractures, including immediate and long-term studies. *J Nucl Med* 1979;**20**:1227−31.
9. Jordan E, Choe D, Miller T, Chamarthy M, Brook A, Freeman LM. Utility of bone scintigraphy to determine the appropriate vertebral augmentation levels. *Clin Nucl Med* 2010;**35**:687−91.
10. Jin ZG, Shen SM, Gao JX, Wang XP, Liu HM, Lu WX, et al. Identification of fresh and old vertebral compression fractures by MRI. *Fa Yi Xue Za Zhi* 2011;**27**:274−6.
11. Masala S, Schillaci O, Massari F, Danieli R, Ursone A, Fiori R, et al. MRI and bone scan imaging in the preoperative evaluation of painful vertebral fractures treated with vertebroplasty and kyphoplasty. *In Vivo* 2005;**19**:1055−60.
12. Kim JH, Kim JI, Jang BH, Seo JG. The comparison of bone scan and MRI in osteoporotic compression fractures. *Asian Spine J* 2010;**4**:89−95.
13. Kazawa N. T2WI MRI and MRI-MDCT correlations of the osteoporotic vertebral compressive fractures. *Eur J Radiol* 2012;**81**:1630−6.
14. Pizones J, Izquierdo E, Alvarez P, Sanchez-Mariscal F, Zuniga L, Chimeno P, et al. Impact of magnetic resonance imaging on decision making for thoracolumbar traumatic fracture diagnosis and treatment. *Eur Spine J* 2011;**20**(Suppl. 3):390−6.
15. Rao RD, Singrakhia MD. Painful osteoporotic vertebral fracture. Pathogenesis, evaluation, and roles of vertebroplasty and kyphoplasty in its management. *J Bone Joint Surg Am* 2003;**85**:2010−22.
16. Sarli M, Perez Manghi FC, Gallo R, Zanchetta JR. The vacuum cleft sign: an uncommon radiological sign. *Osteoporos Int* 2005;**16**:1210−4.
17. Takahara K, Kamimura M, Nakagawa H, Hashidate H, Uchiyama S. Radiographic evaluation of vertebral fractures in osteoporotic patients. *J Clin Neurosci* 2007;**14**:122−6.