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MRI and Bone Scan Imaging in the Preoperative Evaluation of Painful Vertebral Fractures Treated with Vertebroplasty and Kyphoplasty

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Abstract. *Background: This study compared the role and timing of bone scintigraphy and magnetic resonance imaging (MRI) in the evaluation of vertebral compression fractures (VCFs), before treatment with vertebroplasty and kyphoplasty. To our knowledge, no prior articles have described, in osteoporotic and pathological vertebral fractures, the role of MRI and bone scintigraphy as pre-procedural work up in those patients candidated to undergo spinal interventional procedures. Materials and Methods: A retrospective chart review was performed of thirty patients treated with interventional procedures for painful vertebral fractures at our institution between January 2002 and July 2003. Results: In patients, selected after evaluation with MRI and bone scan imaging, both procedures demonstrated swift pain relief associated with vertebral resistance augmentation. Conclusion: MRI revealed itself to be equivalent to bone scan imaging in selecting patients to be treated with vertebroplasty and kyphoplasty in the first 3/4 months, while bone scintigraphy was more accurate in the evaluation of elderly fractures (>3/4 months). MRI was superior to bone scintigraphy in vertebral collapses due to multiple myeloma.*

The vertebral fracture is defined as a reduction in height of the vertebral body beyond 20% of its initial dimensions (1-4). This condition is generated when the combination of the axial and rotational forces on the spine exceed the resistance offered by the vertebral body. Primary osteoporosis is responsible for about 85% of vertebral compression fractures (VCFs), while secondary osteoporosis and neoplasty determine the remaining 15% (5).

Vertebroplasty, the percutaneous injection of polymethylmethacrylate (PMMA) bone cement into the vertebral body, first described by Galibert *et al.* in 1984, has been applied to the treatment of collapsed vertebrae due to aggressive hemangiomas, osteolytic tumors and osteoporosis (6). Kyphoplasty is a recent treatment for VCF, first employed by Reiley in 1997, which, through the swelling of an inflatable bone tamp (IBT) into the collapsed vertebral body, elevates the endplates, thereby restoring the vertebral body height and creating a void to be filled with cement (7). To obtain these notable results, the patient must be precisely studied with diagnostic imaging.

Patients, with a documented fracture on a conventional radiograph, in particular if affected by multiple fractures of uncertain age and non-localized pain, usually undergo adjunctive imaging in the form of magnetic resonance imaging (MRI) and bone scan imaging. Bone scintigraphy cannot aid in differentiating acute from chronic fractures, since the bone scan may show elevated tracer uptake for as long as 12 months after the fracture (8-11). Instead, increased tracer uptake at the level of a vertebral compression fracture is highly predictive of a positive clinical response after percutaneous vertebroplasty and kyphoplasty (8).

A literature review revealed the lack of studies dedicated to pre-operative evaluation of VCFs. This is the first investigation to compare the role of scintigraphy and MRI in the evaluation of patients treated with vertebroplasty and kyphoplasty.

Our main aim was to delineate the utility and the importance of the two diagnostic imaging techniques in the pre-procedural assessment of differently aged vertebral fractures in order to clarify and standardize the international guidelines in pre-operative patient evaluation and management.

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Materials and Methods

From January 2002 to July 2003, 30 patients (F=17, M=13; ages ranged from 50 to 91 years, mean age 70) with vertebral collapses were treated. Respectively, 24 (F=16, M=8) had fractures due to osteoporosis and 6 (F=1, M=5) due to primary and metastatic osteolytic neoplasms (4 myelomas and 2 metastasis).

Twenty-three patients underwent a single level treatment (8 Dorsal: D7 number of patients 3, D8 n=1, D10 n=1 , D12 n=3; 15 Lumbar: L1 n=4, L2 n=3, L3 n=3, L4 n=3, L5 n=2), while 7 were treated at multiple levels (9 Dorsal: D7 n=2, D9 n=1, D10 n=1, D11 n=2, D12 n=3; 8 Lumbar: L1 n=2, L2 n=2, L3 n=2, L4 n=1, L5 n=1) for 40 levels in total (Table I).

MRI of the spine is the most useful test for defining the cause of spinal pain, evidencing epidural or neural foraminal disease and cord compression caused by tumor extension or bone fragment retropulsion, determining fracture age, ruling out a malignant tumor and selecting the appropriate treatment. MRI (Philips, Gyroscan Intera Master, 1.5 Tesla, Holland) was executed in T1 (TR 450 msec - TE 13 msec - NSA 4 - FOV 325 - Matrix 256), T2 (TR 2952 msec - TE 120 msec - NSA 6 - FOV 325 - Matrix 512) and STIR T2 (TR 1650 msec - TE 22 msec - NSA 3 - FOV 325 - Matrix 304) sequences to show altered signal intensity. Two experienced radiologists independently evaluated the images obtained by MRI, both being unaware of each others findings.

Bone scintigraphy was performed 3 hours post-intravenous administration of ~740 MBq of Tc 99 m-methylene diphosphonate (Tc 99m-MDP) using a large field-of-view dual head single photon emission computed tomography system fitted with low-energy high resolution collimators (Millennium VG from General Electric, Milwaukee, USA). Whole-body acquisition was done using the continuous method in a 256 x 1024 matrix. For spinal lesions, planar static images of the areas of interest were then acquired in a 256 x 256 matrix for 5 minutes per view. Two experienced nuclear medicine physicians independently evaluated the scan findings.

Table I. *Description of the 30 patients enrolled in the study.*

Patient	Treatment	Gender	Age	Treated levels	Related pathology
1	Kyphoplasty	m	19/08/33	L1	osteoporosis
2	Kyphoplasty	m	19/02/55	D7	osteoporosis
3	Kyphoplasty	f	05/09/26	L4	osteoporosis
4	Kyphoplasty	f	18/07/30	D7	osteoporosis
5	Kyphoplasty	f	06/04/31	D12	osteoporosis
6	Kyphoplasty	f	17/10/40	L3	osteoporosis
7	Kyphoplasty	f	28/02/28	L2, L4	osteoporosis
8	Kyphoplasty	m	08/08/33	L2	osteoporosis
9	Kyphoplasty	m	19/01/42	L2	osteoporosis
10	Kyphoplasty	m	28/11/44	L4	myeloma
11	Vertebroplasty	f	30/05/25	L5/D7	osteoporosis
12	Vertebroplasty	f	08/07/44	L1	osteoporosis
13	Vertebroplasty	m	16/07/34	D11, L1/D7	myeloma
14	Vertebroplasty	f	28/09/17	L5	osteoporosis
15	Vertebroplasty	f	01/11/45	D7	osteoporosis
16	Vertebroplasty	f	28/01/37	D12	osteoporosis
17	Vertebroplasty	f	25/12/23	D11, D12	osteoporosis
18	Vertebroplasty	f	20/05/50	L1	osteoporosis
19	Vertebroplasty	m	14/01/34	D9, D10/ D12, L3	myeloma
20	Vertebroplasty	f	24/07/21	L4	metastasis
21	Vertebroplasty	m	12/01/21	L1	osteoporosis
22	Vertebroplasty	f	02/04/31	L3	osteoporosis
23	Vertebroplasty	m	22/09/39	L2	myeloma
24	Vertebroplasty	m	16/03/33	D8	metastasis
25	Vertebroplasty	f	08/08/33	L3	osteoporosis
26	Vertebroplasty	f	07/02/43	D12, L1	osteoporosis
27	Vertebroplasty	m	08/12/13	D10	osteoporosis
28	Vertebroplasty	m	19/01/42	L5	osteoporosis
29	Vertebroplasty	m	26/09/55	L2, L3	osteoporosis
30	Vertebroplasty	f	31/10/20	D12	osteoporosis

Results

In this study, 40 painful vertebral levels were treated; in 16, the pre-procedural assessement was more accurate through evaluation with MRI STIR-sequences, 10 with bone scan scintigraphy, while in the remaining 14 the contribution of both these techniques was equivalent (Table II). Ten patients underwent a kyphoplasty procedure (F=5, M=5), whereas another 20 were treated utilizing vertebroplasty (F=12, M=8).

The procedures were successfully performed on our group of patients, whose vertebral body resistance was considerably increased and improvement was swift and persistent in reducing all symptoms (12-17), decreasing from an average of 7.8 points of VAS to 2.2 (VAS of Huskisson = Visual analog scale, pain score with points assigned subjectively from patient pre- and post-procedure in a range between 0 absence of grief and 10 maximum pain) (Table III). Moreover, in those patients treated with kyphoplasty, normal vertebral body morphology was restored with a clinical and radiological reduction of the kyphosis and with a positive effect on the lumbar compensatory hyperlordosis (18-23). No conditions were found where there were extravasations of PMMA in the epidural or foraminal sites with marrow or radicular compression.

Discussion

This retrospective study, conducted at our institution, yielded 33 percutaneous treatment sessions that were performed after obtaining, in the same day, MRI and bone scan imaging for painful, osteoporotic and neoplastic compression fractures in 30 patients.

Vertebroplasty and kyphoplasty proved to be effective treatments to induce a reduction in or relief from spinal pain in patients and a reinforcement of the vertebral body (24-27). The patient selection for interventional radiology procedures is often complicated by the presence of multiple fractures or

Table II. *Different accuracy in pre-procedural evaluation of vertebral body fractures with MRI and bone scan scintigraphy, also evaluating the underling pathology.*

Role of Scintigraphy = MRI -Stir		→	14 levels
Role of Scintigraphy < MRI -Stir		→	16 levels
Role of Scintigraphy > MRI -Stir		→	10 levels
	Total of Patients = 30		
	Total of Levels = 40		
Osteoporosis			
> Scintigraphy	6		
> MRI-STIR	11		
Scintigraphy = MRI	12		
Myeloma			
> Scintigraphy	2		
> MRI-STIR	5		
Scintigraphy = MRI	2		
Metastasis			
> Scintigraphy	2		
> MRI-STIR	0		
Scintigraphy = MRI	0		

Table III. *Visual analog scale, pain score with points assigned subjectively from patient pre- and post-procedure in a range between 0 absence of grief and 10 maximum pain.*

Patient	VAS PRE	VAS POST
1	8	3
2	6	2
3	8	1
4	8	1
5	9	2
6	8	2
7	8	1
8	8	1
9	8	2
10	8	4
11	8	1
12	9	2
13	7	2
14	7	2
15	7	2
16	7	2
17	7	2
18	8	2
19	9	1
20	9	1
21	8	3
22	7	4
23	7	4
24	8	3
25	8	3
26	8	2
27	8	4
28	8	3
29	8	3
30	8	3

non-localized pain. MRI and bone scan imaging performed in the same day are quite useful in triaging patients before performing percutaneous therapy. In MRI the signal intensity of a benign compression fracture varies according to the age of the fracture. Acute osteoporotic fractures (<2 months old) characteristically show a focal band-like area of low signal intensity adjacent to the fractured endplate on T1WI. On T2WI, a collapsed vertebra is essentially isointense with adjacent non-collapsed vertebrae. On post-contrast medium-enhanced T1WI images, there is partial or complete equalization of the signal intensity of the collapsed vertebra with that of the adjacent non-collapsed vertebrae (termed "return to normal signal intensity"). Particularly the sequences with suppression of fat are of valid assistance in the determination of the age of the fracture; showing the presence of intraspongious edema testifies for a recent fracture and is predictive of a favorable response to an interventional procedure over the spine (28, 29). On spin-echo T1-weighted images (T1WI), a malignant compression fracture shows complete replacement of normal bone marrow with diffuse low signal intensity in the whole of the vertebral body. On spin-echo T2-weighted images (T2WI), normal to high signal intensity is seen in the collapsed vertebra; the distribution of signal intensity can either be homogeneous or heterogeneous. Abnormal enhancement is seen in the vertebrae on post-contrast medium-enhanced images, particularly those obtained after fat suppression. The enhancement effect is mostly marked and inhomogeneous with diffuse or patchy distribution. Rarely, incomplete bone marrow replacement (round or irregular foci of low signal intensity on T1WI) with some residual normal bone marrow signal is seen in the vertebral body. The morphological features that are considered to be suggestive of malignant compression fractures include a convex bulge involving the whole of the posterior cortex of the vertebral body, involvement of the pedicles and the presence of an epidural and/or paraspinal soft tissue mass.

The size of the low signal intensity areas seen on T1WI in acute compression fractures remains unchanged (or even increased) in the initial 2-4 months and then gradually reverts to normal. Chronic benign osteoporotic fractures usually show normal signal intensity of the vertebral body on both T1WI and T2WI. In particular, the suppression fat sequence is of valid assistance in the determination of the age of the fracture; showing the presence of intraspongious edema, testifies for a recent fracture and is predictive of a favorable response to interventional procedure over the spine (28, 29).

Diffusion-weighted MRI is a recent tool that may help to distinguish metastatic from osteoporotic vertebral compression

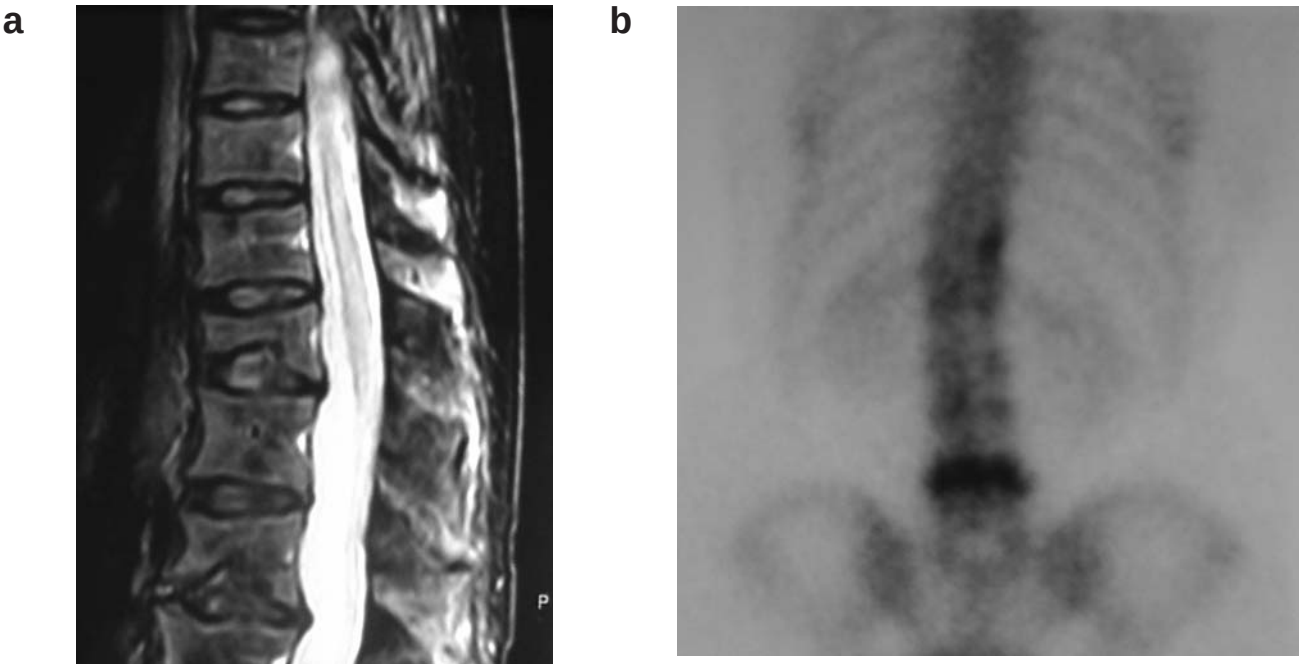

Figure 1 a,b. *Patient, 78 years old, female, vertebral compression fracture of L4 due to osteoporosis; pain onset with minor trauma 2 months before treatment. a) Pre-treatment sagittal MRI (T2-weighted TSE with fat suppression sequence) shows increased signal intensity in the whole vertebra revealing the presence of intraspongious edema. b) Increased tracer uptake at the level of a VCF, revealed by bone scan imaging, is highly predictive of positive clinical response to percutaneous treatment.*

fractures (30, 31). Malignant compression fractures demonstrate hypointense or isointense signals compared to adjacent vertebrae on diffusion-weighted MR sequences. However, in some patients, imaging findings remain equivocal. In cases in which the etiology of a compression fracture is in question, a biopsy can easily be performed coaxially through the needle, before injection of the cement.

Bone scan imaging with Tc 99m-MDP evaluates qualitatively the activity of osteoblastic cells through uptake of the tracer within the vertebral body. Bone scans provide useful information about bone turnover and, thereby, identify any vertebral fracture that has an ongoing healing process. Bone scans are sensitive for the detection of fractures, but they have low specificity for the diagnosis of underlying disease. An additional limitation of bone scanning is that increased bone turnover can be detected as long as 1 year following a vertebral fracture, not permitting the differentiation of acute from chronic fractures. This limits the ability of a bone scan to demonstrate the acuity of an osteoporotic vertebral fracture, and it is not helpful for determining the source of the pain. Distinguishing among vertebral fractures, neoplasms and infections is difficult on a bone scan, unless multiple metastatic lesions are clearly identified. Bone scanning plays a role in identifying osteoporotic fractures in patients who have negative findings on plain radiographs and in identifying additional fractures at other levels. Increased tracer uptake at the level of a VCF, revealed by bone scan imaging, is highly predictive of positive clinical response to percutaneous treatment. In multiple myeloma bone scintigraphy may demonstrate increased uptake, but may be normal or equivocal (32).

MRI imaging offers the advantage over bone scan imaging of accurately assessing vertebral levels involved by fractures and the presence and degree of bony retropulsion. Conversely, bone scan imaging is superior to MRI in showing the whole skeletal system and providing a functional assessment of bone turnover, which is increased in healing fractures.

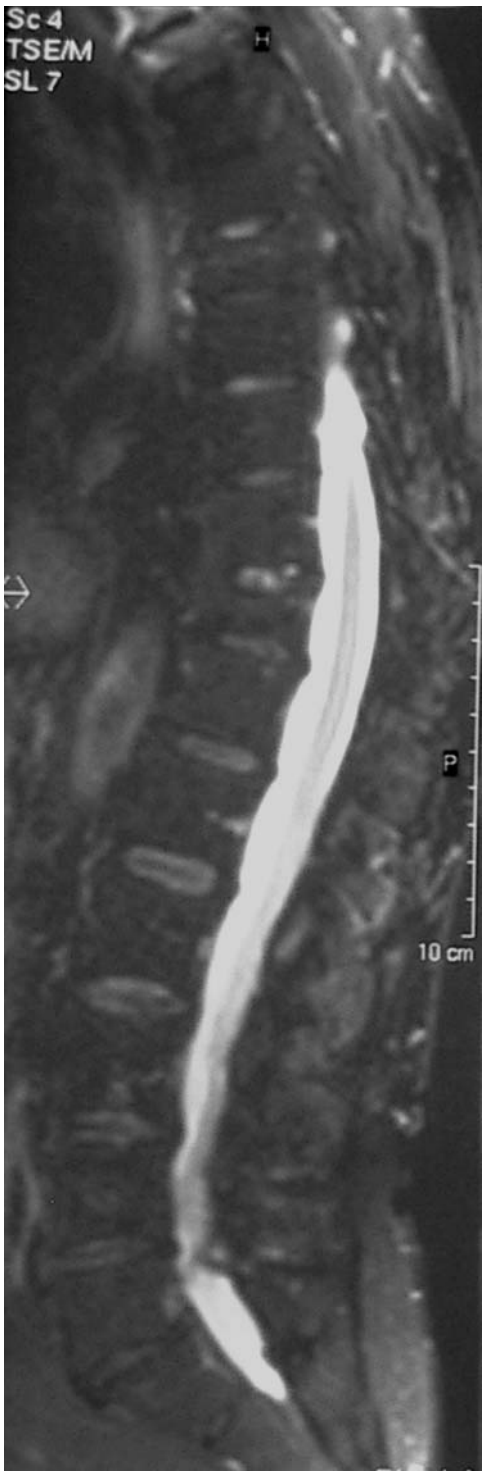

Figure 2 a,b. *Patient, 75 years old, male, vertebral compression fracture of D7 and D11 due to secondary osteoporosis based on high corticosteroid doses; pain onset with minor trauma 7 months before treatment. a) Pre-treatment sagittal MRI (T2-weighted TSE with fat suppression sequence) shows normal signal intensity in the collapsed vertebrae. b) Bone scan imaging, tracer uptake at the level of a VCF still remain increased after several months from vertebral fractures (left rib uptake was due to a recent trauma).*

MRI is extremely useful in the evaluation of VCFs, especially when fractures of different ages are present, because it demonstrates characteristic changes in the marrow signal that vary with the age of the fracture. Acute and subacute fractures, less than 90 days old, are hypointense in signal on T1-weighted images and hyperintense on T2-weighted and short T1 inversion recovery (STIR) sequences.

To our knowledge, there have been no previous studies comparing the use of adjunctive imaging strategies, beyond plain film imaging to properly select patients who will experience pain relief with vertebroplasty and kyphoplasty. This chart review was performed to analyze and characterize the role of MRI and bone scan imaging as part of the pre-procedural work up in those patients candidated to undergo spinal interventional procedures. In our experience, supported by the results of this study, we consider it fundamental that the patient undergo a pre-operative MRI-STIR and scintigraphic evaluation in the presence of a vertebral fracture dated less than 3/4 months (Figure 1 a,b). Contrary to this, because the signal intensity areas seen on MRI-STIR in acute and subacute compression fractures change after 2-4 months and gradually revert to normal, the gold standard in the evaluation of old fractures (>3/4 months) becomes bone scan scintigraphy (Figure 2 a,b).

The absent or equivocal tracer uptake in multiple myeloma bone scintigraphy make it necessary to perform an MRI evaluation in order to analyze and characterize these vertebral collapses. However, in order to confirm these results and to clarify and standardize international guidelines in pre-operative

patient evaluation and management, a larger series of patients comparatively evaluated with this two techniques is necessary.

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