

# The Application of SPECT in the Diagnosis of Osteoporotic Vertebral Compression Fractures

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## Abstract

**Objective:** The aim of this study is to investigate the feasibility and effectiveness of single photon emission computed tomography (SPECT) as a replacement of magnetic resonance imaging (MRI) in the diagnosis of osteoporotic vertebral compression fractures (OVCF) under special situation.

**Methods:** A total case of 43 vertebral compression fractures treated with percutaneous kyphoplasty (PKP) in 35 patients from Feb 10<sup>th</sup>, 2014 to Jan 12<sup>th</sup>, 2016 were collected. These patients, including 13 cases implanted with contraceptive ring, 14 cases implanted with steel plate and 8 cases implanted with metal stent, were diagnosed by SPECT but not MRI. The balloon was embedded into the vertebral body from the pedicle to reset the fractured vertebral body. PMMA was then filled into the balloon-produced space. The feasibility and effectiveness of SPECT were evaluated by observing reduction of fracture and postoperative pain symptoms.

**Results:** The mean follow-up was  $19.3 \pm 2.7$  months (ranged from 15 to 24 months). All patients were diagnosed by SPECT preoperatively. The preoperative mean loss of anterior and mid vertebral body heights were  $(13.2 \pm 4.1)$  mm and  $(11.7 \pm 4.0)$  mm, respectively, and the postoperative (48 h) mean loss were  $(4.7 \pm 2.4)$  mm and  $(4.2 \pm 2.0)$  mm, respectively. The mean kyphosis angle was improved from  $(22.9^\circ \pm 8.5^\circ)$  to  $(9.4^\circ \pm 2.9^\circ)$ . The mean Visual Analogue Scale (VAS) decreased significantly from  $8.4 \pm 1.0$  to  $2.2 \pm 1.0$  in two days after operation. There are 2 cases of bone cement leakage occurred, including 1 case of leaking around the vertebral and 1 case of leaking into the disc.

**Conclusion:** SPECT, as a replacement of MRI under special situation, can definitely diagnose painful vertebrae.

**Keywords:** SPECT; Osteoporosis; Vertebral compression fractures; Percutaneous kyphoplasty

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## Introduction

Owing to the aging population, the incidence of osteoporosis has undergone a dramatic increase in the past decades, resulting in the continuous rise of osteoporotic vertebral compression fractures (OVCF) [1, 2]. In recent years, percutaneous kyphoplasty (PKP) has been proved to be a safe and effective minimally invasive surgery for OVCF [3-5], and has attracted extensive attention of doctors and researchers. Accurate diagnosis of painful vertebrae is essential to ensure the curative effect of PKP. Magnetic resonance imaging (MRI) [6, 7] is an effective method to determine painful vertebrae (low signal on T1WI, high signal on T2WI and STIR) during the diagnosis of OVCF. A

large number of patients, however, cannot be diagnosed by MRI due to various reasons, causing great difficulties in the confirmation of painful vertebrae. For imaging all bones, single photon emission computed tomography (SPECT) has been seen as an effective method for detecting the early bone metabolism and blood flow changes in painful vertebrae, as well as a mass of radiocontrast agent aggregated around the active sites of bone metabolism. The weakened bone metabolism and inflammation of old fractured vertebral body (non-painful vertebrae) result in inadequate or even no radiocontrast agent aggregated around the fractured vertebral body. To diagnose the painful vertebrae in OVCF, all patients were required to intake the appropriate half-

life radioactive drugs. Once the drug reached the lesion region, the site of the lesions can thus be detected and presented in the form of image by computer due to the radioactive decay of the drug. In the present study, SPECT was selected to diagnose painful vertebrae and its feasibility and effectiveness were investigated and explored.

## Materials and Method

### Patients

A total of 35 cases (13 males and 22 females) of OVCF were collected from Feb 10<sup>th</sup>, 2014 to Jan 12<sup>th</sup>, 2016 in this work. The patient's ages range from 60 to 90 years old, with an average of  $70.1 \pm 8$  years old. The specimen involve 43 vertebral bodies, including 1 case of T10, 1 case of T11, 6 cases of T12, 9 case of L1, 11 cases of L2, 6 cases of L3, 8 cases of L4 and 1 case of L5. No clinical symptom of spinal and nerves was found before operation. These patients, involving 13 cases implanted with contraceptive ring, 14 cases implanted with steel plate and 8 cases implanted with metal stent, were diagnosed by SPECT but not MRI due to the metal implants (except titanium and degaussed metal). All patients were excluded pathological fracture caused by cancer, tuberculosis or infections, and were diagnosed as OVCF by X-ray, computed tomography (CT) and bone mineral density (BMD). The result of SPECT is obtained by two experienced nuclear medicine physicians and two experienced orthopedic surgeons. The standard of painful vertebrae: A mass of radiocontrast agent aggregate around the fractured vertebral body could be observed in the result of SPECT.

### Surgical technique

The operation was processed under general anaesthesia. Guide wires were firstly inserted with the aim of obtaining bilateral transpedicular access to the fractured vertebral body. The small incision was enlarged by larger cannulae sequentially. Kyphon balloon tamps (Tecres S.P.A. Sommacampagna, Italy) were inserted and placed in the two-thirds anterior of the vertebral body through the cannulae on the lateral view, and covered both sides of the midline on the anteroposterior view. The balloon was embedded into the vertebral body from the pedicle to reset the fractured vertebral body and to create a void for the injection of cement. When the pressure reached to 300 psi or the balloon contacted with the endplate, the inflation was stopped. Polymethylmethacrylate (PMMA) cement was then injected slowly to fill the void. The bone cement introducer was removed carefully once the cement hardened. Patients were allowed to walk 24 h after the operation.

### Efficacy assessments

The overall evaluation of operation was obtained depends on the kyphosis angle and vertebral height measured by the follow X-ray and the score of the Visual Analogue Scale (VAS) before and after the surgery.

### Statistical analysis

All data were processed by using paired sample t-tests, with  $P \leq 0.05$  considered statistically significant between two sets of data, but  $P > 0.05$  is contrary.

### Ethical considerations

A protocol detailing the above procedure was approved by the ethics committee of our hospital, and written informed consent was obtained from all patients.

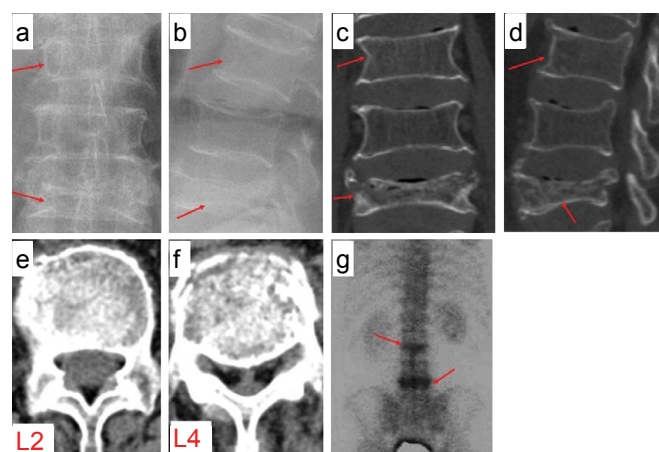
## Results

All the patients were successfully completed PKP. As shown in **Figure 1**, the painful vertebrae of an eighty two years old male patient who was excluded pathological fracture by X-ray (**Figures 1a and 1b**) and CT (**Figures 1c-1f**) was diagnosed by SPECT (**Figure 1g**). The postoperative X-ray (**Figure 2**) showed two fractured vertebral bodies recovered and the cement distributed well. The mean follow-up was  $19.3 \pm 2.7$  months (ranged from 15 to 24 months). The postoperative loss of anterior and mid vertebral body heights had statistically significant improvement compared with preoperative values (**Table 1**;  $p < 0.05$ ). The postoperative kyphosis angle also had statistically significant improvement compared with preoperative values (**Table 1**;  $p < 0.05$ ). Additionally, the postoperative VAS had statistically significant improvement compared with preoperative values (**Table 1**;  $p < 0.05$ ). Moreover, no statistically significant differences between the postoperative and the latest follow-up assessments for any of the evaluated efficacy measures (**Table 1**;  $p > 0.05$ ). However, 2 cases of bone cement leakage occurred, including 1 case of leaking around the vertebral and 1 case of leaking into the disc. No obvious complications were found during follow-up period.

## Discussion

### The application of MRI in vertebral compression fracture

OVCF, which caused by osteoporosis, is still a common disease in the field of spine surgery. The appearance of PKP provides



**Figure 1** An eighty two years old male patient crushed, and caused low back pain for four days. On examination, there were soft tissues tenderness and percussive pain around L2 and L4. Preoperative X-ray (a and b) showed obvious L4 fracture, but L2 was inverted. The results of preoperative CT (c-f) were consistent with X-ray. Preoperative SPECT (g) indicated L2 and L4 are the painful vertebrae because of a mass of radio contrast agent gathered around L2 and L4.

an effective method for the treatment of OVCF. However, to guarantee the efficacy of the operation, an accurate diagnosis of painful vertebrae became very important.

Painful vertebrae is the main applicable object of filling bone cement. Therefore, accurately diagnosing painful vertebrae is an essential factor for ensuring the effective treatment of PKP [8, 9]. Clinically, the surface tender points of the fractured vertebral body was used to diagnose whether this vertebral body is in charge of the pain symptom or not [10]. However, the severe osteoporosis results in a wide low back pain and thoracodorsal pain, and then bringing difficulties in diagnosing painful vertebrae through a general physical examination for many patients. X-ray and CT play an important role in diagnosing the fractured vertebral body, but they cannot diagnose the fractured vertebral body without obvious morphological changes and cannot clearly distinguish the differences between the painful vertebrae and old fractured vertebral body [11, 12]. MRI is a type of tomography which uses the physical phenomenon of magnetic resonance to obtain the electromagnetic signal from the human body, and reconstruct the human body structure. As a non-invasive examination method, MRI is not only can clearly reveal the morphological changes of the vertebral body but also can reveal spinal cord edema caused by the fractured vertebral body. The painful vertebrae in MRI exhibits as low signal on T1WI and high signal on T2WI and STIR. Therefore, MRI has been recognized as the one of the most important methods for accurate diagnosis of painful vertebrae due to its non-invasiveness and accuracy [13].

Although MRI has been regarded as a useful method for accurate diagnosis of painful vertebrae, the strong magnetic field and radio-frequency field of MRI are likely to cause cardiac pacemaker failure, and also easily lead to varied body metal implants moving. Besides, the metal implants also damage the patient due to the fever in the electromagnetic waves. Therefore,

the patients with metal implants are strictly prohibited the MRI examination, which limited the further applications of MRI in accurately diagnosing painful vertebrae.

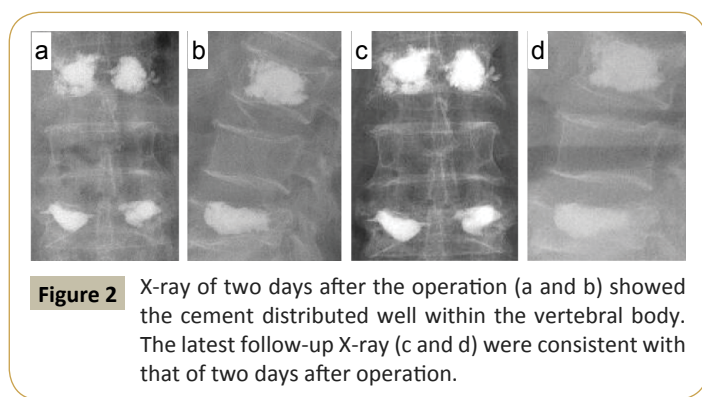
### The application of SPECT in the diagnosis of OVCF

As discussed above, some patients cannot be diagnosed by MRI due to the strong magnetic field and radio-frequency field. Therefore, to overcome the defects of MRI, SPECT was proposed as an effective method to accurately diagnose painful vertebrae.

SPECT has been widely applied as a method of screening and monitoring malignancy bone metastasis in clinical due to its convenience, painless and accuracy. According to the relevant literatures [14-16], the accuracy of SPECT in the diagnosis of early bone metastases reached to 85.7% ~ 94.3%. By SPECT, the image of the all bone can be exhibited after injecting radiocontrast agent which based on the different intakes of radiocontrast agent between the normal bone tissue and the diseased vertebral body. Radiocontrast agent increased significantly in the active site of bone metabolism, and aggregated as well surrounding tissue of the fractured vertebral body because of its osteoclasts and osteoblasts, but the radiocontrast agent aggregation significantly reduced in the dissolution of bone lesions and bone necrosis.

Although the old fractured vertebral body can be definitely diagnosed [17], the painful vertebrae could not be diagnosed by X-ray and CT. The old fractured vertebral body has no inflammatory reactions and no obvious change in bone metabolism. Different from the old fractured vertebral body, trauma induced painful vertebrae and its surrounding soft tissue can develop a series of symptoms, including infiltration of inflammatory cells, acceleration of blood flow, congestion and enhancement of bone metabolism. SPECT showed that there is a large number of radiocontrast agent aggregation in the painful vertebrae while the old fractured vertebral body are contrary, making they can be effectively distinguished. Relevant studies showed that SPECT can accurately diagnose early skeletal lesions and can help to diagnose painful vertebrae, as well as guide the operation of PKP and evaluate the efficacy [18-20]. Therefore, SPECT, as a replacement of MRI under special situation, can definitely diagnose painful vertebrae.

According to the above results, SPECT is confirmed with significant advantages in the accurate diagnosis of the painful vertebrae in vertebral compression fracture, and revealing tremendous potentials in clinic. In this case, all 35 OVCF patients with metal implants were diagnosed by SPECT but not MRI before



**Figure 2** X-ray of two days after the operation (a and b) showed the cement distributed well within the vertebral body. The latest follow-up X-ray (c and d) were consistent with that of two days after operation.

**Table 1** Efficacy dates (mean; variance) at preoperative, postoperative and final follow-up assessments (n=35).

	Preop.	Postop.	Final follow-up	Preop. vs. postop.		Postop. vs. final follow-up	
				t	P	t	P
Anterior	13.2 ± 4.1	4.7 ± 2.4	4.2 ± 2.2	16.31	<0.0001	-2.62	0.0645
Middle	11.7 ± 4.0	4.2 ± 2.0	3.8 ± 1.6	16.69	<0.0001	0.44	0.3306
Kyphotic angle (°)	22.9 ± 8.5	9.4 ± 2.9	8.8 ± 2.9	9.67	<0.0001	1.55	0.0651
VAS	8.4 ± 1.0	2.2 ± 1.0	2.0 ± 0.9	23.22	<0.0001	1.00	0.1602

Anterior: the loss of anterior vertebral body heights; Middle: the loss of mid vertebral body heights; Preop.: Preoperative; Postop.: Postoperative; vs.: versus; VAS: Visual Analogue Scale

operation in this study. SPECT showed that there are a large number of radiocontrast agents aggregated around the fractured vertebral body. All patients were successfully completed surgery. The vertebral heights, kyphosis angle and VAS scores were significantly improved after PKP and maintained latest follow-up in our patients. Our results revealed that all painful vertebrae of patients were successfully diagnosed and this diagnosis is very meaningful for the following treatment. In course of follow-up, all patients expressed satisfaction of PKP and no patients have obvious complications, indicating all vertebrae diagnosed by SPECT were painful vertebrae.

## Conclusion

Based on the results, SPECT could successfully diagnose painful vertebrae in the special patients who have metal implants in body, and this successful diagnosis provides a powerful guarantee for further treatments. In the present study, 35 patients who cannot be diagnosed by MRI received the examination of SPECT and all of their painful vertebrae were successfully diagnosed. After diagnosis, all of these patients were treated in time and recovered well without complications. Therefore, these results indicated the SPECT is a simple, effective, painless and non-invasive examination in diagnosing painful vertebrae of OVCF, and the SPECT showed the great potential for replacing MRI in the case of special patients who cannot be diagnosed by MRI due to the implanted metal in body.

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