Diagnostic value of SPECT/CT bone imaging in fresh osteoporotic vertebral compression fractures

Yanjun Zhao[1#] **MD,**
Di Zhang[2,3#] **BD,**
Ping Tang[1] **BD**

[#]Yanjun Zhao and Di Zhang contributed equally to this study

1. Department of nuclear medicine, Wuxi No.2 People's Hospital, Jiangsu, China
2. School of nursing, Zhejiang Chinese Medical University, Zhejiang, China
3. Department of geriatric rehabilitation, Wuxi Central rehabilitation hospital, Jiangsu, China

Keywords: SPECT/CT - Osteoporosis - Compression fracture - MRI

Corresponding author:
Ping Tang BD,
Department of Nuclear Medicine,
Wuxi Second People's Hospital
No. 68, Zhongshan Road,
Wuxi City, Jiangsu Province,
214002, China
Tel:+86-0510-68562508
pingtang1510@126.com

Received:
3 March 2022
Accepted revised:
30 May 2022

Abstract

Objective: To investigate the diagnostic value of single photon emission computed tomography/computed tomography (SPECT/CT) bone imaging in fresh osteoporotic vertebral compression fractures. **Materials and Methods:** The imaging data of 30 patients with osteoporosis (10 males and 20 females; aged 50~93 years) who received SPECT/CT bone imaging and spinal magnetic resonance imaging (MRI) in our hospital from June 2018 to June 2021 were analyzed retrospectively. Single photon emission computed tomography/CT bone imaging and spinal MRI were analyzed by two experienced specialists. Kappa consistency test and pairing were used for the diagnostic results of the two groups χ^2 test (McNemar test) for statistical analysis. **Results:** Fifty one vertebral fractures were detected in 30 patients, including 41 fresh vertebral fractures and 10 old vertebral fractures by SPECT/CT bone imaging; MRI revealed 40 fresh vertebral fractures and 11 old vertebral fractures. Single photon emission computed tomography/CT bone imaging and spinal MRI had good consistency in the diagnosis of fresh osteoporotic vertebral compression fractures (Kappa=0.820, P<0.001), and there was no significant difference between the two imaging methods in the diagnosis of osteoporotic vertebral fractures (P=1.000). **Conclusions:** The value of SPECT/CT in the localization and characterization of osteoporotic fresh vertebral compression fractures is similar to that of MRI. At the same time, SPECT/CT can also find some bone lesions that cannot be displayed by conventional MRI. Especially when patients have MRI contraindications, SPECT/CT bone imaging can be used as the preferred imaging method.

Hell J Nucl Med 2022; 25(2): 138-142 *Epub ahead of print: 3 August 2022* *Published online: 29 August 2022*

Introduction

With the increase of human life expectancy and the gradual transition to an ageing population structure, senile osteoporosis has become a global health challenge. Osteoporosis is a systemic chronic metabolic skeletal disease that affects millions of people worldwide. It is characterised by low bone mass and deterioration of bone tissue microarchitecture, and it is often associated with vertebral compression fractures [1]. The vertebral body with a fresh fracture is often the 'responsible vertebral body' that causes a patient's preoperative pain, and the preoperative positioning of this vertebral body is a key factor affecting the success or failure of surgery, especially for patients with multiple vertebral compression fractures [2]. At present, magnetic resonance imaging (MRI) of the spine is a common method for diagnosing fresh osteoporotic vertebral compression fractures [3-6]. However, some patients are unable to undergo MRI examination due to claustrophobia and the presence of paramagnetic metal materials, such as pacemakers and artificial metal valves, in their bodies, so the 'responsible vertebral body' may not be discovered in time. Single-photon emission computed tomography/computed tomography (SPECT/CT) has the advantages of early detection of lesions, high sensitivity, and accurate positioning [7]. The purpose of this study was to investigate the value of SPECT/CT bone imaging in the diagnosis of new osteoporotic vertebral compression fractures.

Materials and Methods

Clinical data

A retrospective analysis was made on 30 patients in our hospital from June 2018 to June

2021, with osteoporosis due to chest, waist and back pain caused by minor trauma or daily activities; among them were 10 males and 20 females, aged 50-93 (average 72.4±9.8) years. This study was approved by the hospital ethics committee. Inclusion criteria included an osteoporosis diagnosis obtained through dual energy X-rays absorptiometry, with a recent and clear history of trauma or low-energy injury, and high clinical suspicion of vertebral compression fracture; pathological fractures caused by tumours or infectious diseases were excluded.

SPECT/CT bone imaging method

A 740-925MBq injection of technetium-99m-methyl diphosphonate (^{99m}Tc-MDP) (provided by Shanghai Xinke Pharmaceutical Co., Ltd., Suzhou Branch, radiochemical purity >95%) was administered through the cubital vein, and two to four hours later, the Holland Philips Precedence SPECT/CT (16 rows) instrument was used for whole-body plane and local SPECT/CT tomographic fusion image acquisition; a low-energy high-resolution collimator was selected, with a 512×512 matrix, an energy peak of 140keV and window width at 20%. The whole-body acquisition scanning speed was 150mm/min and the anterior and posterior images were collected. Single photon emission computed tomography/CT tomographic fusion imaging and CT acquisition conditions were as follows: 120kV, 100mA, collimator width of 0.6mm, layer thickness of 5mm, interval of 5mm, image reconstruction layer thickness of 2mm, interval of 1mm.Single photon emission computed tomography acquisition parameters were as follows: Low-energy high-resolution collimator selected, energy peak of 140keV, window width at 20%, continuous acquisition 360°, double probe rotation 180°, step 6°, 15s/frame, a 64×64 matrix. The original SPECT images were reconstructed using the Astonish program.Single photon emission computed tomography/CT image fusion was performed using the built-in fusion view software.

Spine MRI method

Sagittal spin echo T1-weighted imaging (T1WI), fast spin echo T2WI, and short time inversion recovery (STIR) were performed using a GE 1.5T Signa MR scanner and a body coil. Specifications were as follows: T1WI: TR 460ms, TE 10ms, T2WI: TR 2600ms, TE 124ms, STIR: TR 3000ms, TE 52ms, TI 150ms, layer thickness of 4mm, layer interval of 1mm.

Image analysis

The SPECT/CT images and MRI were analysed by two experienced specialist physicians independently and blindly. If the results of the two physicians were consistent, the data was valid, and if the results were inconsistent, the data was excluded. Fresh vertebral fractures include acute and subacute vertebral fractures. Acute fractures are fractures that occur within three weeks, subacute fractures occur within 4-12 weeks, and fractures after 12 weeks are old fractures [8].

Single photon emission computed tomography/CT image evaluation criteria were as follows: According to the SPECT/CT tomographic fusion image in the sagittal plane, the fractured vertebral body (T) and the adjacent normal vertebral body (NT) were outlined, respectively, and the average radioactivity count in the region of interest was measured. Its ratio, that is, the target/non-target (T/NT) ratio, was then calculated. Computed tomography findings included a depressed, flattened and wedge-shaped vertebral body, a high-density shadow formed by overlapping banded bone trabeculae in the vertebral body, a transparent fracture line in the vertebral bone cortex, and when combined with clinical data and CT signs, except for a bone tumour, an osteophyte had formed by hyperosteogeny and infectious bone lesions; T/NT >2.44 indicated a fresh vertebral compression fracture, and T/NT <1.04 indicated an old vertebral compression fracture [9].

Magnetic resonance imaging evaluation criteria were as follows: A fresh vertebral fracture showed a low signal on the T1WI or was mixed with a little high signal, a high signal on the T2WI and STIR, with vertebral body depression, flattening, a wedge-shaped deformation and no paravertebral soft tissue mass or accessory structure involvement. Old vertebral fractures showed a low signal on the T1WI, T2WI and STIR.

Statistical processing

The SPSS 23.0 statistical software was used to analyse the data. The Kappa consistency test and paired χ^2 test (McNemar's test) were used for statistical analysis of the diagnostic results of the two groups. A Kappa value ≥0.75 indicated good consistency, a Kappa value ≥0.4 and <0.75 indicated fair consistency and a Kappa value <0.4 indicated poor consistency. A P value of <0.05 was considered statistically significant.

Results

Comparison of MRI and SPECT/CT in judging fresh or old vertebral fractures

A total of 51 vertebral body fractures were detected in 30 patients, of which, 41 fresh fractures and 10 old fractures were found by SPECT/CT bone imaging; 40 fresh fractures and 11 old fractures were found by MRI. After statistical analysis, SPECT/CT bone imaging and spinal MRI showed good consistency in evaluating osteoporotic fresh vertebral compression fractures (Kappa value=0.820, P<0.001), and there was no statistically significant difference in the diagnostic results between the two methods (P=1.000), as shown in Table 1.

Comparison of SPECT/CT and MRI results in the localisation of diseased vertebrae

Single photon emission computed tomography/CT bone imaging and MRI were consistent in the diagnosis of 39 fresh vertebral fractures and nine old vertebral fractures. The typical images are shown in Figure 1. In addition to T12 compression fractures, SPECT/CT bone imaging also found associated sacral fractures. Two vertebral bodies were diagnosed as fresh fractures in SPECT/CT bone imaging and old fractures on the MRI, and one vertebral body was diagnosed as a

fresh fracture on the MRI and an old fracture on SPECT/CT bone imaging.

Discussion

Previously, scholars have conducted relevant research on how to precisely locate fresh fractured vertebrae. Some scholars have reported that fresh vertebral fractures can be accurately diagnosed by local tenderness of the spinous process [8], but clinically, some patients have extensive chest and back pain, low back pain and radiation pain of the flank and ribs due to severe osteoporosis. Therefore, it is difficult to pinpoint the location of fresh fractured vertebral bodies based on physical examination alone. Ordinary radiographs and CT can only analyse the anatomical structure.

Table 1. *Specific diagnostic results of the two methods and kappa and McNemar tests.*

SPECT/CT	MR		Total
	fresh fractures	old fractures	
fresh fractures	39	2	41
old fractures	1	9	10
Total	40	11	51

Kappa=0.820, P<0.001; McNemar test P>0.05.

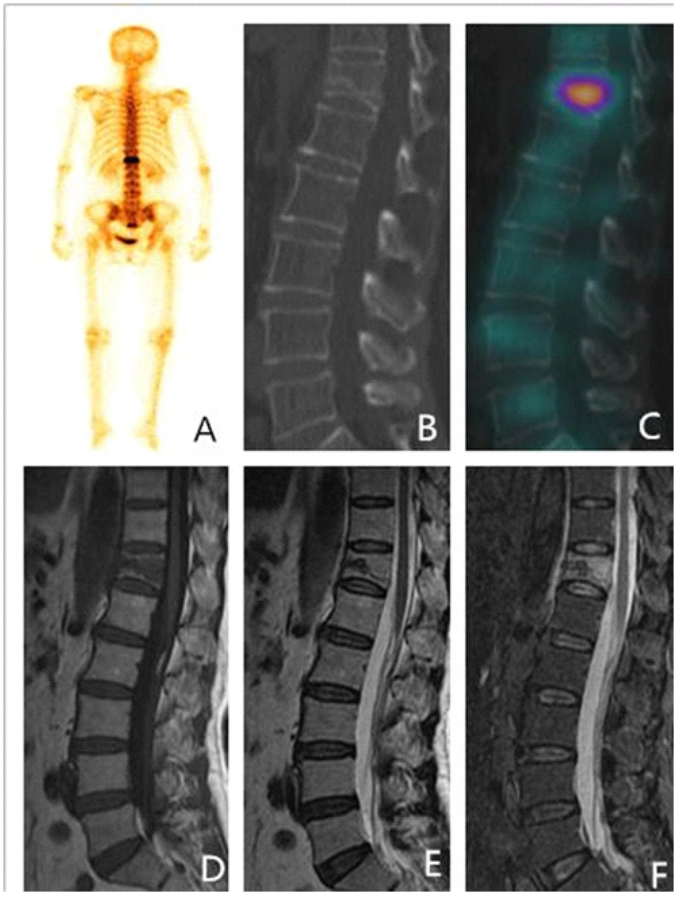

Figure 1. Technetium-99m-MDP SPECT/CT bone imaging and MRI in patients with osteoporosis (female, 68 years old). A: Whole body bone imaging showed abnormal increase of T12 vertebral body and sacral bone metabolism; B: CT showed wedge-shaped changes of T12 vertebral body; C: The SPECT/CT tomographic fusion image showed T12 wedge-shaped transformation with abnormal concentration of radioactivity, and the T / TN was 5.32;D: T12 vertebral body showed low signal on T1WI sequence in MRI image; E: T2WI sequence in MRI image showed that T12 vertebral body showed contour signal; F. In MRI images, stir sequence showed that T12 vertebral body showed high signal.

The presence of a compression fracture is determined by observing or measuring the height of the vertebral body, but the morphological changes of some vertebral body compression fractures are not obvious. Therefore, plain radiography and CT cannot distinguish new fractures from old fractures due to these limitations [9]. Because an MRI can clearly show the morphological changes of the vertebral body and display traumatic bone marrow oedema after a vertebral fracture, it is considered to be the best method for accurately localising fresh vertebral compression fractures [10]. There were significant differences in T1WI and T2WI signals between fresh and old fractures. However, some patients with old OVCF have obstacles in fracture healing, causing bone resorption or liquefaction, resulting in MRI findings inconsistent with the above-mentioned findings. Make the local T1 lengthen and T2 shorten accordingly, and interfere with the diagnostic results. Moreover, some patients need to choose another effective examination method to determine the fresh fractured vertebral body because they are equipped with paramagnetic metal implants such as cardiac pacemaker, coronary stent and dental fixator, or because they cannot accept MRI examination due to claustrophobia.

With the rapid development of nuclear medicine technology, the important application value of SPECT/CT bone imaging for some benign bone lesions has gradually become prominent. The commonly used imaging agent for SPECT/CT bone imaging is ^{99m}Tc-MDP. After intravenous injection, ^{99m}Tc-MDP enters the bone with the blood circulation and is retained in the bone tissue by ion exchange or chemical absorption [11]. The principle is that after ^{99m}Tc-MDP is injected into the vein, it is absorbed on the surface of the hydroxyapatite crystal of the bone through ion exchange or chemical absorption. The uptake of imaging agents by local bone tissue is proportional to blood flow and bone salt metabolism, so significant radioactive concentrations can be seen in active osteogenesis sites [12]. In fresh fractures, the abnormal uptake of radionuclides at the fracture end is caused by factors such as local blood flow, vigorous metabolic renewal, active osteoblast repair and calcium salt deposition. With the healing of fractures, local blood flow, metabolism and osteoblast repair tend to be normal, and radionuclide uptake tend to be normal. Single photon emission computed tomography/CT can not only reflect the characteristics of SPECT bone metabolism and CT anatomical structure but also organically combine the two images, complement each other and improve the diagnostic efficiency [13]. Single photon emission computed tomography/CT bone imaging is an effective method for the diagnosis of vertebral fractures [14]. It is consistent with the research results of this paper.

The results of this study showed SPECT/CT bone imaging found 41 fresh vertebral fractures and 10 old fractures, while MRI found a total of 40 fresh fractures and 11 old fractures. Two of the 41 fresh fractures diagnosed by SPECT/CT bone imaging were diagnosed as old fractures by MRI, while one of the 40 fresh fractures diagnosed by MRI was diagnosed as an old fracture by SPECT/CT bone imaging. The reason the SPECT/CT was positive and the MRI was negative in two of the vertebral bodies may have been that bone marrow oedema and bleeding were absorbed during fracture repair, resulting in a low signal on the MRI STIR sequence, while SPECT/CT showed a high radioactive uptake due to increased local blood flow, bone trabecular and revascularisation and increased bone metabolism. After repair of a vertebral fracture, the tracer concentration decreases with time. The tracer concentration in some patients may be as long as one year, but an MRI shows old fractures, which may also be a reason for false positives in SPECT/CT imaging. In the other vertebral body, the positive MRI and negative SPECT/CT may have been related to the reduction of local blood flow caused by a vertebral fracture injury. One patient's symptoms improved significantly after percutaneous vertebroplasty, and two other patients had confirmed fresh fractures in MRI after three months. The inconsistency in diagnosis of the above two methods could be caused by different imaging principles. The results of this study showed that the two imaging methods had good consistency in the diagnosis of osteoporotic vertebral fractures (Kappa=0.820, $P<0.001$), and there was no significant difference between the two methods ($P>0.05$). The results of this study are superior to those reported in the literature [15], indicating that SPECT/CT bone imaging and MRI have the same diagnostic performance for the diagnosis of osteoporotic vertebral fractures. Single photon emission computed tomography/CT bone imaging is an effective and reliable imaging diagnostic method, especially when patients have MRI contraindications. Single photon emission computed tomography/CT bone imaging can be used as a preferred imaging examination method.

Single photon emission computed tomography/CT is an organic fusion of SPECT functional imaging and CT anatomical imaging. It is characterised by a wide scanning range and short scanning time. It has been widely used in the diagnosis and differential diagnosis of bone tumours, especially in the identification of benign and malignant bone lesions [16, 17]. In recent years, with the rapid development of nuclear medicine technology in orthopaedic diseases, SPECT/CT bone imaging has been gradually applied to the diagnosis of bone trauma and fractures. The results of this study showed that in addition to vertebral fractures, five rib fractures, two sacral fractures and one iliac bone metastasis were found on SPECT/CT bone imaging, indicating that SPECT/CT bone imaging can detect fractures in more parts of the body and can simultaneously determine whether there are multiple bone metastases throughout the entire body. In this regard, SPECT/CT bone imaging has more advantages than MRI, which is conducive to the comprehensive evaluation of patients' general condition and can provide objective evidence for clinical decision-making.

In conclusion, this study shows that SPECT/CT is similar in value to MRI in localisation and characterisation of osteoporotic fresh vertebral compression fractures. Additionally, SPECT/CT can also locate some combined skeletal lesions that cannot be displayed by conventional MRI. Especially for patients with contraindications to MRI, SPECT/CT bone imaging can be the preferred imaging method. However, due to the relatively small number of cases included in this study, it is still necessary to expand the sample size in future research to further verify these conclusions.

The authors declare that they have no conflicts of interest.

Bibliography

1. Armas LA, Recker RR. Pathophysiology of osteoporosis: new mechanistic insights. *Endocrinol Metab Clin North Am* 2012; 41(3): 475-86.
2. Parreira PCS, Maher CG, Megale RZ et al. An overview of clinical guidelines for the management of vertebral compression fracture: a systematic review. *Spine J* 2017; 17(12): 1932-8.
3. Garg B, Dixit V, Batra S et al. Non-surgical management of acute osteoporotic vertebral compression fracture: A review. *J Clin Orthop Trauma* 2017; 8(2): 131-8.
4. Rajasekaran S, Kanna RM, Schnake KJ et al. Osteoporotic Thoracolumbar Fractures-How Are They Different?-Classification and Treatment Algorithm. *J Orthop Trauma* 2017; 31 Suppl 4: S49-S56.
5. Prost S, Pesenti S, Fuentes S et al. Treatment of osteoporotic vertebral fractures. *Orthop Traumatol Surg Res* 2021; 107(1S): 102779.
6. Yun JS, Lee HD, Kwack KS, Park S. Use of proton density fat fraction MRI to predict the radiographic progression of osteoporotic vertebral compression fracture. *Eur Radiol* 2021; 31(6): 3582-9.
7. Li YB, Zheng X, Wang R et al. SPECT/CT versus MRI in localizing active lesions in patients with osteoporotic vertebral compression fractures. *Nucl Med Commun* 2018; 39(7): 610-7.
8. Astur N, Avanzi O. Balloon Kyphoplasty in the Treatment of Neoplastic Spine Lesions: A Systematic Review. *Global Spine J* 2019; 9(3): 348-56.
9. Zhu ZH. Observation on the effect of MRI and CT on the diagnosis of thoracolumbar vertebral compression fractures in the elderly. *Imag Res Med Appl* 2021; 5(19): 166-7.
10. Soldati E, Rossi F, Vicente J et al. Survey of MRI Usefulness for the Clinical Assessment of Bone Microstructure. *Int J Mol Sci* 2021; 22(5): 2509.
11. Hirschmann MT, Davda K, Rasch H et al. Clinical value of combined single photon emission computerized tomography and conventional computer tomography (SPECT/CT) in sports medicine. *Sports Med Arthrosc Rev* 2011; 19(2): 174-81.
12. Yang L, Chen Y. Application of SPECT/CT and ^{18}F-NaF PET/CT in patients with osteoarthritis. *Chin J Nucl Med Mol Imaging* 2019; 39(01): 41-4.
13. Shi HC. Clinical application of SPECT/CT: using its advantage over other medical imaging modalities. *Chin J Nucl Med Mol Imaging* 2017; 37(07): 385-7.
14. Ding HY, Cai L, Chen Y et al. ^{99m}Tc-MDP Whole-body Bone Imaging Combined with Local SPECT/CT Tomography in Diagnosing Sacral Insufficiency Fracture. *Chin J Med Imaging* 2019; 27(08): 612-7.
15. Dafydd D, Salem S, Zerizer I et al. The value of combined assessment of vertebral fractures with ^{99m}Tc MDP scintigraphy and MRI in selecting and planning percutaneous vertebroplasty. *Nucl Med Commun* 2014; 35(7): 755-61.
16. Zhou M, Lin JS, Yan W et al. The value of SPECT/CT imaging in the diagnosis of benign and malignant spinal lesions. *Chin Med Dev Information* 2019; 25 (09): 62-3.
17. McLoughlin LC, O'Kelly F, O'Brien C et al. The improved accuracy of planar bone scintigraphy by adding single photon emission computed tomography (SPECT/CT) to detect skeletal metastases from prostate cancer. *Ir J Med Sci* 2016; 185(1): 101-5.