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Does Bone SPECT Actually Have Lower Sensitivity for Detecting Vertebral Metastasis Than MRI?

Shigeru Kosuda, Tatsumi Kaji, Hisaaki Yokoyama, Tokuzo Yokokawa, Michiaki Katayama, Toshiyuki Iriye, Minoru Uematsu and Shoichi Kusano

Department of Radiology, National Defense Medical College, Tokorozawa, Japan

We compared the ability of bone SPECT and MRI to detect vertebral metastasis. **Methods:** Skeletal scintigraphy, including planar and SPECT imaging, and spinal MRI examinations, were performed in 22 cancer patients in whom a total of 88 metastatic foci and 12 degenerative joint disease lesions were detected. Metastatic foci were defined as lesions that suggested metastasis on MRI and/or bone destruction on radiographs or CT and/or aggravation of increased tracer uptakes on serial bone scans. Image reconstruction of axial, coronal and sagittal sections was processed in a 128 × 128 matrix. MRI studies were performed with a 1.5 tesla signal scanner using fast spin-echo sequences. T1- and T2-weighted images were obtained in the sagittal plane. **Results:** Twenty patients had at least one vertebral metastasis. MRI diagnosed 86 of the 88 (97.7%) metastatic foci; bone SPECT correctly diagnosed 81 of 88 (92.0%); and planar imaging detected 62 of 88 (70.4%). The two vertebrae with metastasis not detected by MRI were clearly seen by bone SPECT. Extra-vertebral body metastases (e.g., in the pedicle, lamina, transverse and spinous processes) were, however, most often detected by SPECT, followed by MRI and planar imaging (40 versus 32 versus 4). **Conclusion:** Vertebral SPECT, using high-resolution SPECT equipment, produced excellent results that were comparable to and complementary with MRI in detecting vertebral metastasis. Our data suggest that vertebral SPECT is superior to MRI in detecting extra-vertebral body metastasis.

Key Words: bone SPECT; MRI; vertebral metastasis

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Bone scintigraphy is the most common imaging technique for detecting osseous metastasis throughout the skeleton. The most frequently performed radionuclide study, in Japan alone it accounts for approximately 30% of the procedures performed by institutions specializing in nuclear medicine. There are, however, reports that skeletal scintigraphy is less effective than MRI in detecting vertebral metastasis (*1–9*). But in these studies, bone planar imaging, not bone SPECT imaging, was compared with MRI. SPECT has proven superior to planar imaging in detecting various bone diseases (*10–13*). Because no studies comparing them have been reported, it is not clear whether bone SPECT has a lower sensitivity than MRI in detecting focal vertebral metastasis. In view of the importance of the early detection of vertebral metastasis and our great interest in bone SPECT, we thought it of clinical value that such a comparison between the two tomographic modalities be made.

MATERIALS AND METHODS

We retrospectively reviewed skeletal scintigrams and MRI studies of the thoracolumbar spine. Both skeletal scintigraphies, including planar and SPECT imaging, and spinal MRI examinations were performed in 22 cancer patients who had complained of back pain. Their ages ranged from 18 to 80 yr (mean 61.1 yr). Histologically proven diagnoses were as follows: nine cases of breast carcinoma (all women), five of prostatic carcinoma (all men), and one each of pulmonary carcinoma (male), renal cell carcinoma (male), pancreatic carcinoma (male), Wilms' tumor (female), hepatocellular carcinoma (male) and adenocarcinoma of unknown primary site (male).

All patients were followed for at least 18 mo after skeletal scintigraphy and spinal MRI examination. The final diagnosis of vertebral or disk lesions was based on the results of all radiological studies, including repeated skeletal scintigraphies, MRI, computed tomographic (CT) scans, plain radiographs and the subsequent clinical course.

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For correspondence or reprints contact: Shigeru Kosuda, MD, Division of Nuclear Medicine, Department of Internal Medicine, 1500 E. Medical Center Dr., University of Michigan Medical Center, Ann Arbor, MI 48109-0028.

All patients but one underwent skeletal scintigraphies and spinal MRI examinations within 2 wk of each other. One patient underwent MRI study 2 mo after skeletal scintigraphy. Twenty patients had MRI studies after bone scans to confirm vertebral metastasis and to examine spinal cord involvement. In two patients, bone scans were performed after spinal MRI examination to survey other osseous metastases throughout the skeleton. All patients underwent both planar and SPECT studies on the same day. In general, bone SPECT imaging of the spine was implemented when whole-body scanning, including spot views, showed increased or equivocal tracer accumulation in the spine or the patient had back pain despite no increased tracer accumulation.

Bone planar imaging was performed using a gamma camera with a high-resolution, low-energy, parallel-hole collimator 3–4 hr after injection of 740 MBq (20 mCi) of ^{99m}Tc-methylene diphosphonate (MDP). Both whole-body imaging and posterior spot views of the spine (400–500 kcts each) were taken. SPECT imaging of the spine was performed immediately after planar imaging using a high-resolution SPECT system (Toshiba 9300A/HG) with three-head rotating cameras equipped with high-resolution, low-energy, parallel-hole collimators.

Data were accumulated for 30 angles (4° per step, 120° total), with 42 sec per angle for each detector. The counts per projection image ranged from 22–27.5 kcts, with a total study count from 2800–3110 kcts. The acquisition time for the projection data was 21 min. A Butterworth prefilter and filtered back projection using a Shepp and Logan filter with 0.18 cycles/pixel cutoff frequency were used for image reconstruction of axial, coronal and sagittal sections in a 128 × 128 matrix. Neither tissue attenuation correction nor scatter subtraction was processed. The resolution was 11.6 mm FWHM at the center of the reconstructed slices, which were two pixels thick (3.2 mm). The film-density characteristic curve algorithm was selected, by which the best quality film of vertebral SPECT was obtained.

MRI studies were performed with a 1.5 tesla signal scanner, using fast spin-echo sequences. All patients were studied with a repetition time msec/echo time msec of 340/11 for T1-weighted images (T1WI) and 4000/100 for T2-weighted images (T2WI), obtained in the sagittal plane. Section thickness, interslice gap, acquisition matrix and acquisition time for T1WI and T2WI were 5 mm, 1 mm, 256 × 192, 4.32″ and 3.12″, respectively. Three patients underwent gadolinium-enhanced T1WI in the sagittal sections.

Two reviewers independently interpreted each bone planar and vertebral SPECT image. Two other diagnostic radiologists independently reviewed each MR image.

RESULTS

MRI versus SPECT

Initially, we defined vertebral metastasis as metastasis of the vertebral body and/or extra-vertebral body (posterior processes). All 22 patients underwent spinal MRI examination. Twenty had at least one metastatic lesion, and of these, four had both metastatic vertebrae and degenerative joint disease. The two remaining patients had degenerative joint disease alone, without abnormal findings on MRI. All MRI-detected metastatic lesions showed low signal intensity on T1WI and iso- or high signal intensity on T2WI.

For the 22 patients, MRI was superior to bone SPECT in detecting vertebral metastases in eight (36.4%). Four of these patients had false-positive bone SPECT for degenerative joint disease, and the other four had false-negative bone SPECT for metastasis, which may explain the lower detection ability of bone SPECT compared with MRI. Of the four patients with negative SPECT, three had breast cancer (adenocarcinoma) and one Wilms' tumor. In the other eight patients, both techniques yielded positive results and showed a similar anatomic distribution of tumor involvement in the vertebrae. Bone SPECT was superior to MRI in detecting vertebral metastases in five patients. This was due mainly to bone SPECT's ability to detect metastatic foci present only in extra-vertebral bodies (i.e., the pedicle, lamina, transverse, spinous, mamillary and inferior articular processes), which MRI failed to do. Only one of these five patients had osseous metastasis in the pedicle alone, with no vertebral body metastasis. Two of the five showed false-positive MRI of the vertebrae for degenerative joint disease (one with low intensity on T1WI and iso-intensity on T2WI and the other with high intensity on both T1WI and T2WI), which produced no abnormal findings on bone SPECT. In one patient, SPECT and MRI results were complementary, both indicating two vertebrae with false-negative bone SPECT and two vertebrae with false-negative MRI for metastatic foci.

In six of the 20 patients (30%) with vertebral metastases, MRI showed spinal cord and/or dural compression due to a bulging tumor or collapse of the vertebral body.

TABLE 1
Comparison of Sensitivity for Planar Imaging, Vertebral SPECT and Spinal MRI of Metastasis and Degenerative Joint Disease

Disease	Planar	SPECT	MRI
Metastasis	62/88 [20/20] (70.4%)	81/88 [20/20] (92.0%)	86/88 [20/20] (97.7%)
DJD	6/12 [3/6] (50.0%)	8/12 [4/6] (66.7%)	4/12 [2/6] (33.3%)
Total	68/100 (68.0%)	89/100 (89.0%)	90/100 (90.0%)

Numbers in brackets are comparison of patients to lesions. The 22 cancer patients consisted of 16 with metastasis only, 4 with both metastasis and DJD and 2 with DJD only.
DJD = degenerative joint disease.

Planar versus SPECT versus MRI in Detecting Metastatic Foci

In the 20 patients with at least one vertebral metastasis, 86, 81 and 62 vertebrae were diagnosed as having metastases by MRI, vertebral SPECT and planar imaging, respectively. Two vertebrae with metastasis were not detected by MRI but were clearly seen by vertebral SPECT. The metastatic foci were defined as lesions that had a low signal intensity on T1WI and iso- or high-signal intensity on T2WI and/or bone destruction on radiography or CT and/or aggravation of increased tracer uptakes on serial bone scans.

Twenty patients showed a total of 88 vertebral metastases (24 thoracic, 58 lumbar and 6 sacral lesions). Four of them also had a total of eight vertebral lesions with degenerative joint disease, and of these, two had four vertebral lesions with degenerative joint disease without osseous metastasis throughout the skeleton.

In detecting the 88 metastatic foci (Table 1), MRI was the most efficient (97.7%), followed by bone SPECT (92.0%) and bone planar imaging (70.4%). On the other hand, bone SPECT was the most efficient in detecting degenerative joint disease (Table 1) (66.7%), followed by bone planar imaging (50.0%) and MRI (33.3%). Of the 20 patients with osseous metastasis, 15 also had osseous metastases remote from the thoracolumbar spine, and five had thoracolumbar spine metastases found only on whole-body scintigraphy.

Table 2 shows the number of metastatic foci in vertebral or extra-vertebral bodies detected by the three diagnostic modalities. In metastases of vertebral bodies, MRI had the highest detection frequency, followed by SPECT and planar imaging.

TABLE 2
Comparison of Sensitivity of Planar Imaging, Vertebral SPECT and Spinal MRI in the Detection of Intra- and Extra-vertebral Body Metastasis

Vertebral metastasis	Planar	SPECT	MRI
Vertebral body	60	79	85
Extra-vertebral body	4	40	32
Total	64	119	117

Extra-vertebral body metastases, were, however, most often detected by SPECT followed by MRI and planar imaging.

We believe this investigation contains no significant bias regarding the patient population of this comparative study, because this study compares SPECT and MRI, not metastasis and degenerative joint disease.

Figure 1 shows a SPECT image of a patient with cancer of unknown primary site that was useful in detecting extra-vertebral body metastases MRI failed to detect.

DISCUSSION

Phosphate skeletal scintigraphy was once believed to be sensitive for the early detection of metastatic bone diseases, because it could observe abnormalities months before plain radiographic studies showed any evidence of osseous metastasis (*14, 15*). Skeletal scintigraphy's preeminence was shattered, however, with the advent of MRI, which has a greater sensitivity and specificity than skeletal scintigraphy in detecting metastatic foci. Indeed, skeletal scintigraphy is only capable of finding approximately 30% (18%–69%) of presumed metastatic bone lesions detected by MRI (*1–5, 7, 8*).

Several reports that compared skeletal scintigraphy and MRI in detecting spinal metastasis favored the latter as a useful, complementary method for patients with equivocal or negative bone-scan findings (*1–9*). MRI certainly has a higher specificity than bone scintigraphy, and its findings of decreased intensity on T1WI and increased or iso-intensity on T2WI are highly suggestive of osseous metastasis. We believe, however, that, because of its ability to assess the whole body easily and its availability (despite the higher cost in Japan), skeletal scintigraphy remains the diagnostic method of choice for initial screening for osseous metastasis.

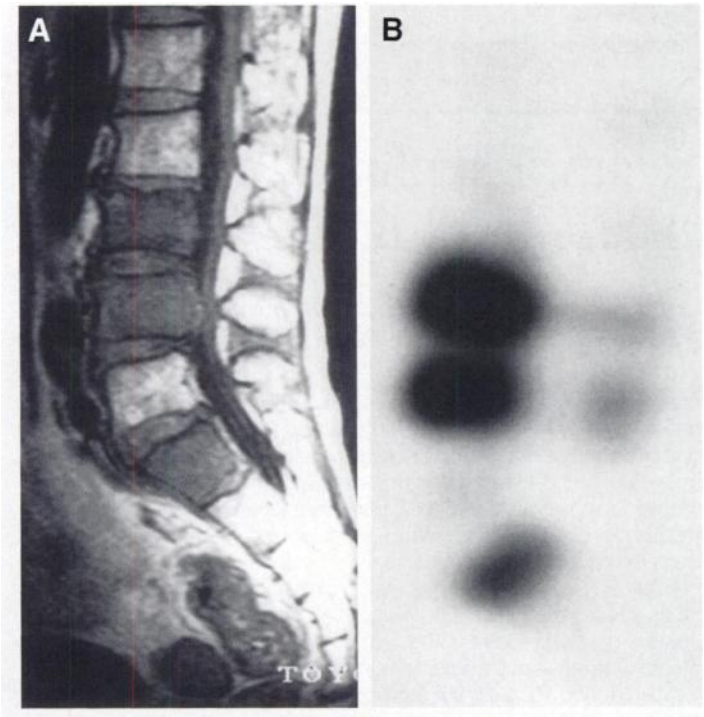

FIGURE 1. SPECT image of a 60-yr-old man with cancer of unknown primary site complaining of back pain. (A) T1-weighted MR image (sagittal section) shows low signal intensity in the vertebral bodies of L3, L4 and S1. (B) Vertebral SPECT (sagittal section) reveals increased tracer accumulations not only in the vertebral bodies but also in the spinous processes. Osteolytic changes in the above lesions appeared on bone radiographs taken approximately 6 mo later.

There are two questionable aspects concerning the diagnostic algorithm for cancer patients with suspected vertebral metastasis: one is the appropriateness of MRI immediately after obtaining equivocal or negative scan findings in spite of symptoms; the other is a doubt as to the true significance of bone scanning only for osseous metastasis, other than lesions detected definitely by MRI. MRI often precedes a bone scan in the context of a crammed order-entry system in Japan. It has been associated with false-positive findings for vertebral metastasis and is often unable to differentiate degenerative joint disease from metastasis. Both hemangioma and Schmorl's nodule show low signal intensity on T1WI and high signal intensity on T2WI.

During the last decade, SPECT has assumed an important position in routine diagnosis. High-resolution SPECT equipment with three-head cameras, in particular, enable us to perform bone SPECT conveniently. We believe that it is critical to compare bone SPECT findings with spinal MRI findings to determine the accuracy of bone SPECT in detecting vertebral metastasis. Furthermore, it would be valuable to confirm on bone SPECT whether MRI-detected lesions are truly abnormal and if there is discordance between the two regarding the extent of lesions.

In our series, vertebral SPECT showed a much higher ability to detect metastatic foci than bone planar imaging (92.0% versus 70.4%) and produced results almost comparable with MRI (92.0% versus 97.7%). As for metastatic foci location, SPECT detected less intra-vertebral body metastases than MRI (79 versus 85 foci), although it produced better results than bone planar imaging (79 versus 60 foci). This result, however, was reversed; in detecting extra-vertebral body metastases. MRI detected less extra-vertebral body metastases than vertebral SPECT (32 versus 40 foci). Of a total of 22 patients, five (22.7%) had better results with vertebral SPECT than with MRI, mainly because vertebral SPECT revealed extra-vertebral body metastases that MRI could not find.

The accepted reason for MRI's superiority over bone scan in detecting osseous metastasis is as follows: At first, hematogeneously seeded intramedullary metastasis occurs; then the lesion replaces the normal marrow and produces prolonged relaxation times that differ from the normal marrow on T1WI and T2WI. These processes occur before either intrinsic or reactive metabolic changes in cancellous and cortical bone can be detected by bone scan (*4, 5*). At an earlier stage of vertebral metastasis, it is difficult for planar bone scanning to detect the foci localized in the marrow and/or cancellous bone.

Our results show that vertebral SPECT, using high-resolution SPECT apparatus, provides results comparable with MRI in detecting metastatic foci, which indicates that vertebral SPECT is capable of scanning for minimal changes of vertebral bone mineral turnover occurring in early-stage osseous metastasis. Furthermore, vertebral SPECT might play a helpful and complementary role in differentiating degenerative joint disease from metastasis, because MRI findings of degenerative joint disease and metastasis are sometimes confusing and can be misinterpreted (*16*).

Vertebral SPECT's superiority in detecting extra-vertebral body metastasis may be because the pedicle, lamina and processes consist mainly of compact bone, which is favorable for vertebral SPECT, but not for MRI. Compact or cortical bone metastases may be more common than previously expected (*17*). There is, however, a drawback to vertebral SPECT: lower specificity. In non-neoplastic bone diseases, ^{99m}Tc-labeled phosphate agents often accumulate in congruence with the facet joint, vertebral endplate and osteophyte. Holder et al. (*18*) reported that high-resolution SPECT bone imaging is useful in diagnosing facet syndrome. As shown by Even-Sapir et al. (*19*), sites and patterns of accumulation in vertebral SPECT may be helpful in differentiating metastasis from degenerative joint disease or other benign bone diseases.

When spinal MRI has already been performed, whole-body bone scintigraphy should be performed, because osseous metastases remote from the thoracolumbar spine are frequent. Performing skeletal scintigraphy would also be helpful in confirming suspected false-positive MRI. We believe that patients with equivocal or negative planar bone imaging in spite of back pain should immediately undergo vertebral SPECT because of its greater ability to detect metastasis, especially extra-vertebral body metastasis.

CONCLUSION

Vertebral SPECT, using a high-resolution SPECT camera, produces excellent results, comparable to and complementary with MRI in detecting vertebral metastases. Vertebral SPECT might be superior to MRI in detecting extra-vertebral body metastases. Bone scan is the method of choice to screen for osseous metastases, but high-resolution vertebral SPECT should be performed without hesitation when there is equivocal uptake in the vertebra on planar imaging or a patient has symptoms despite normal scintigraphic and/or MRI findings. We should not, however, neglect MRI, mainly because it offers significant additional information on the dura and spinal cord.

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Bone Marrow Scintigraphy Using Technetium-99m-Antigranulocyte Antibody in Hematologic Disorders

June-Key Chung, Jeongseok Yeo, Dong-Soo Lee, Seonyang Park, Myung-Chul Lee, Byoung-Kook Kim and Chang-Soon Koh

Departments of Nuclear Medicine and Internal Medicine, Seoul National University Hospital, Seoul, Korea

Bone marrow is the primary site for many hematologic disorders. To date, however, no suitable bone marrow imaging method has been found. The present study investigates the usefulness of bone marrow immunoscintigraphy using ^{99m}Tc-labeled antigranulocyte antibody (anti-NCA-95) in 31 patients with hematologic disorders. **Methods:** One milligram of antibody labeled with 259-370 MBq ^{99m}Tc was injected intravenously, and bone marrow images were taken 4 hr later. We also calculated the uptake ratios of lumbar bone marrow-to-background (L/B) and ilium-to-background (I/B). **Results:** Of 15 patients with aplastic anemia, 7 showed diffusely decreased antibody uptake (L/B = 2.3 ± 0.8, I/B = 3.0 ± 0.8) compared to control patients (n = 21, L/B = 8.2 ± 2.5, I/B = 10.3 ± 3.1). Six patients had both decreased and increased uptake areas and two had normal to slightly increased uptake. Of those patients receiving various types of therapy for aplastic anemia, all but one showed increased or irregular uptake. The degree of antibody uptake in the bone marrow correlated with peripheral blood analyses (hemoglobin, white blood cells, platelets). Of six patients with myelodysplastic syndrome, four had irregular uptake and two diffusely decreased uptake. Four patients with myelogenous leukemia showed normal uptake, whereas two with lymphocytic leukemia had decreased uptake. Patients with iron deficiency anemia, pure red cell aplasia or thalassemia minor exhibited normal uptake with bone marrow expansion. **Conclusion:** Immunoscintigraphy with antigranulocyte antibody is a useful method for evaluating the bone marrow status of patients with various hematologic disorders.

Key Words: hematologic disorder; bone marrow scintigraphy; technetium-99m-anti-NCA-95; aplastic anemia; myelodysplastic syndrome

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For correspondence or reprints contact: June-Key Chung, MD, Department of Nuclear Medicine, Seoul National University Hospital, 28 Yungun-dong, Chongno-ku, Seoul 110-744, Korea.