Diagn Interv Radiol 2013; 19:33–40

Hybrid SPECT-CT for characterizing isolated vertebral lesions observed by bone scintigraphy: comparison with planar scintigraphy, SPECT, and CT

Punit Sharma, Varun Singh Dhull, Rama Mohan Reddy, Chandrasekhar Bal, Sanjay Thulkar, Arun Malhotra, Rakesh Kumar

PURPOSE
We aimed to assess the role of single photon emission computed tomography-computed tomography (SPECT-CT) for characterizing isolated vertebral lesions observed by bone scintigraphy compared to planar scintigraphy, SPECT, and CT, and to evaluate the impact of SPECT-CT on patient management.

MATERIALS AND METHODS
Data from 99 patients (mean age, 52.4±18.9 years; females, 58.5%) with 108 isolated vertebral lesions visible on planar bone scintigraphy, who had undergone SPECT-CT of a selected volume, were retrospectively analyzed. Planar scintigraphy, SPECT, CT, and SPECT-CT images were independently evaluated in separate sessions to minimize recall bias. A scoring scale of 1 to 5 was used, with 1 being definitely metastatic, 2 most likely metastatic, 3 indeterminate, 4 most likely benign, and 5 definitely benign. Sensitivity, specificity, and predictive values were calculated; a score ≤3 was defined as metastatic. The areas under the receiver operating characteristic curve were calculated and compared. Clinical and imaging follow-up with or without histopathology were used as a reference standard.

RESULTS
Among the 108 lesions, 49 were indeterminate on planar scintigraphy, 16 on SPECT, and one each on SPECT-CT and CT. SPECT-CT was superior to both planar scintigraphy ($P < 0.001$) and SPECT alone ($P = 0.014$), but not to CT ($P = 0.302$). CT was superior to planar scintigraphy ($P < 0.001$) but only slightly superior to SPECT ($P = 0.063$). SPECT-CT correctly characterized 96% of the indeterminate lesions observed by planar scintigraphy. SPECT-CT had an impact on the clinical management of 60.6% patients compared to planar scintigraphy and 18.1% compared to SPECT.

CONCLUSION
SPECT-CT is better than planar scintigraphy and SPECT alone, but not CT alone, for characterizing equivocal vertebral lesions that are observed by bone scintigraphy, thus SPECT-CT can have a significant impact on patient management.

From the Departments of Nuclear Medicine (P.S., V.S.D., R.M.R., C.B., A.M., R.K. ✉ *rkphulia@yahoo.com*) and Radiodiagnosis (S.T.), All India Institute of Medical Sciences, New Delhi, India.

Received 8 March 2012; revision requested 12 April 2012; revision received 22 April 2012; accepted 26 May 2012.

Published online 3 August 2012
DOI 10.4261/1305-3825.DIR.5790-12.1

Bone is one of the most common sites of distant metastasis in cancer patients, apart from the lung and liver (1). Most bone metastases result from hematogenous dissemination of cancer cells. The mechanism of the development and growth of bone metastases is a multistep process that requires complex interactions between the metastatic cells and the tissue (2). Metastases do not affect all bones with the same pattern and frequency. The spine is the most common site of bone metastasis. Various anatomical and functional imaging modalities are used for detecting and characterizing spinal metastasis. Among them, bone scintigraphy, commonly performed with 99m-technetium methylene diphosphonate (99mTc-MDP), is a widely used procedure that provides a whole-body skeletal survey at a relatively low cost and is usually the initial imaging modality for the assessment of bone metastases (3). Numerous reports emphasize the high sensitivity of bone scintigraphy in the diagnosis of osseous metastases. However, bone scintigraphy lacks specificity due to the known increased blood flow and metabolic reaction of the bone to a variety of disease processes, including osteoarthritis, trauma, and inflammation (4).

Single-photon emission computed tomography (SPECT) improves the lesion-to-background contrast and sensitivity of 99mTc-MDP bone scintigraphy (5). SPECT enables accurate localization of tracer activity, especially in complex skeletal structures, such as the spine, and therefore can improve diagnostic specificity (6). Accurate localization of a suspected lesion that is observed by bone scintigraphy to the pedicle or posterior aspect of the vertebral body using SPECT may improve the specificity of this modality for metastasis (7). However, the specificity of SPECT is also not sufficient for a reliable diagnosis (8). Correlation with high-quality anatomic images, obtained via computed tomography (CT) or magnetic resonance imaging (MRI), may still be needed for diagnosis. Recently acquired anatomic images may not be available at the time of a nuclear medicine procedure (9). Although coregistration of anatomical and functional data obtained separately with different devices has been attempted using external fiducial markers, errors may occur as a result of variations in patient positioning (10). Recently, state of the art hybrid SPECT-CT systems that have become available combine both tomographic scintigraphy and CT, producing a unique combination of the functional and anatomical sets of data (11). These systems allow the field of view of the CT scan to be adapted to line up with the SPECT findings. Some studies have evaluated the efficacy of 99mTc-MDP hybrid SPECT-CT for spinal lesions (12, 13). However, none of these studies compared SPECT-CT with CT alone, which is more widely available and requires less time.

The aim of the present study was to compare the roles of planar scintigraphy, SPECT, CT, and SPECT-CT in the characterization of

isolated spinal lesions observed by bone scintigraphy.

Materials and methods

Patients

This study was a retrospective analysis and was approved by the institutional review board. Between July 2009 and September 2011 a total of 178 patients showed isolated vertebral lesions (≤2 lesions per patient) by bone scintigraphy. Of these, 112 patients had undergone additional SPECT and SPECT-CT. Data from these 112 patients were reevaluated. We excluded 13 patients; five patients had severe motion artifacts, three were excluded because of significant misregistration of the emission and transmission images, two patients were excluded because of missing data and three were excluded because of the lack of availability of a reference standard. A similar pattern of involvement of multiple vertebrae usually suggests a particular etiology; thus, patients with >2 vertebral lesions were not included. As a result, a total of 99 patients were included in the study (known malignancy, 78; no known malignancy, 21)

Radiotracer injection and planar scintigraphy

The patients were intravenously injected 666–925 MBq (18–25 mCi) of 99mTc-MDP, depending on their body weight. Planar scintigraphy was performed 3 hours after radiotracer injection. Planar images were acquired either on a dual head gamma camera (Symbia E, Siemens Medical Solutions, Hoffman Estates, Illinois, USA) or hybrid SPECT-CT dual-head gamma camera (Symbia T6, Siemens Medical Solutions). Anterior and posterior whole body planar images were acquired in a continuous mode by the use of parallel-hole, low-energy, high-resolution collimators, with the patient in the supine position. Images were acquired on the 140-keV photopeak with a 20% symmetrical window and a matrix size of 256×1024. Immediately after acquisition, a nuclear medicine physician evaluated the planar images in addition to the imaging with SPECT with or without SPECT-CT. For patients with ≤2 isolated vertebral lesions, SPECT-CT was performed.

SPECT acquisition

SPECT imaging data were acquired only for the volume defined by planar scintigraphy. All studies were acquired using a hybrid SPECT-CT dual-head gamma camera (Symbia T6, Siemens Medical Solutions). Emission data were acquired with the use of parallel-hole, low-energy, high-resolution collimators, with the patient in the supine position. The acquisition orbits were the body contour orbits over 360° arcs, with the use of 60 stops, each of 6°. For 60 stops, the emission data were acquired for 30 s per stop. The image acquisition matrix was 128×128, and the pixel size was 4.8 mm. Images were acquired on the 140-keV photopeak with a 20% symmetrical window.

CT acquisition

The SPECT imaging was followed by CT examination with the following acquisition parameters: 130 Kv, 100 mAs, pitch of 1, and a 512×512 matrix using standard filters. The CT images were reconstructed with a B08 kernel reconstruction for attenuation correction and B60 kernel for bone imaging. The attenuation maps were created from the input CT image by converting the CT numbers to attenuation numbers, using a look-up table, based on both the CT effective energy spectrum (kV_{eff}) and the emission isotope energy.

Processing of SPECT images and coregistration

All studies were uniformly processed with the commercially available software (e.soft, Siemens Medical Solutions, Knoxville, Tennessee, USA) on a workstation (Syngo Nuclear, Siemens Medical Solutions, Hoffman Estates, Illinois, USA). The SPECT emission image data were processed with ordered-subsets expectation maximization reconstruction software using two iterations and eight subsets. A Gaussian filter with a full width at half maximum of 7.0 was applied. Attenuation correction was applied to these images using the CT-based attenuation maps. Scatter correction was also applied. The corrected SPECT images were again reconstructed with Flash three dimensional software using eight subsets and eight iterations. Subsequently, tomographic slices were generated and displayed as transaxial, coronal, and sagittal slices. SPECT emission images were coregistered and fused with the transmission CT images using the object vs. target matrix method. Fused emission and transmission images were visually inspected for the correctness of coregistration. Studies with significant misregistration were excluded from further analysis.

Image analysis

Two experienced nuclear medicine physicians, who were in consensus, analyzed the planar, SPECT, CT, and SPECT-CT images. The physicians also had experience in reading CT images (four and five years). The readers were blinded to the patients' clinical information, including diagnosis and the findings from other imaging modalities, if any. The planar, SPECT, CT, and SPECT-CT images were evaluated in separate sessions one week apart to minimize recall bias. The images were displayed in a random order. Only the lesions identified by planar scintigraphy were evaluated. In the cases of discrepancy regarding the findings of planar and SPECT images, a consensus was reached after mutual discussion. In the CT images, malignant lesions were suggested by the presence of lytic, sclerotic, or mixed lytic-sclerotic changes. Furthermore, the presence of osteophytes, spondylophytes, subchondral sclerosis, or narrowing of the joint space was regarded as a clear sign that the lesion is benign (14). If there was any discrepancy regarding the CT and SPECT-CT findings, the opinion of an experienced radiologist was sought. Planar scintigraphy, SPECT, CT, and SPECT-CT were compared in terms of the number of equivocal findings and accuracy on a lesion-by-lesion basis. The site and nature of the lesions were also noted.

ROC curve analysis

For the purpose of constructing receiver operating characteristic (ROC) curves, the interpreters used a scoring scale of 1 to 5, in which 1 is definitely metastatic, 2 is most likely metastatic, 3 is indeterminate, 4 is most likely benign, and 5 is definitely benign. For calculating the sensitivity, specificity, and predictive values for planar scintigraphy, SPECT and SPECT-CT, a score ≤3 was taken as metastatic, and a score ≥4 was taken as benign.

Assessment of CT dose

For each patient, the dose parameters such as the volume-weighted CT dose index (CTDIvol) and dose length product (DLP) were available in the patient

protocol and were recorded. DLP is the product of the CTDIvol (mGy) and scan length (cm). The DLP (mGy.cm) was then multiplied with the appropriate conversion factor, depending on the region of the body scanned, to yield the effective dose (mSv) due to additional CT.

Reference standard

Final diagnoses (presence or absence of bone metastases) were derived from clinical and imaging follow-up (CT, MRI, radiography, PET-CT, SPECT-CT) over at least five months with or without histopathology (when available). Increases in the size or changes in the character (lytic to sclerotic) during therapy were considered positive for tumor, whereas lesions with unchanged size and character over five months in the absence of treatment were regarded as benign.

Statistical analysis

We expressed continuous data as the mean±standard deviation, while categorical data were expressed as numbers and percentages. For quantitative interpretation of the ROC curves, the area under the curve (AUC) was calculated and compared. A larger area indicates improved diagnostic performance. Sensitivity, specificity, and predictive values were separately calculated for planar scintigraphy, SPECT, and SPECT-CT, defining a score of ≤3 as malignant. All statistical analysis was performed using commercially available software (Statistical Package for Social Sciences, version 11.5, SPSS Inc., Chicago, Illinois, USA; STATA, STATA Corp., College Station, Texas, USA).

Results

Patients

The patient demographics including age, sex, and indication of skeletal scintigraphy are detailed in Table 1. A total 108 lesions were evaluated in 99 patients. The site of lesions is summarized in Table 2. The additional radiation exposure due to CT was 3.1±1.2 mSv (range, 1.1–5.9 mSv).

Reference standard

Based on the reference standard mentioned above, 74% (80/108) of the lesions were benign, while 26% (28/108) of the lesions were metastatic. Final diagnoses were derived from biopsies in five lesions and imaging follow-up (CT, MRI, radiography, PET-CT, SPECTCT) over at least 4 (range, 4–12) months for 87 lesions. For 16 patients, osteolysis and bone destruction were so obvious on the SPECT-CT images that they were referred immediately to the departments of radiotherapy or orthopedics for further treatment. Follow-up for validation was considered unnecessary in these patients.

Planar scintigraphy, SPECT, CT, and SPECT-CT

On planar scintigraphy, 49 lesions were indeterminate, and on SPECT, 16 lesions were indeterminate. Only one lesion was indeterminate on CT and SPECT-CT. The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of planar scintigraphy, SPECT, and SPECT-CT are detailed in Table 3. For calculating the diagnostic accuracy, intermediate lesions (a score of 3) were considered as malignant. SPECT-CT and CT were especially helpful for lytic lesions (n=15) compared to SPECT and planar bone scintigraphy. SPECT-CT and CT were also helpful in differentiating osteophytes from metastatic lesions in the anterior regions of the vertebral bodies. SPECT-CT and CT showed the classical findings of Schmorl's node in three vertebral body lesions, which were classified as indeterminate by planar bone scintigraphy and SPECT. For two metastatic lesions, which were located very close to the facet joints, planar scintigraphy and SPECT were false negatives and classified them as

Table 1. Patient characteristics

Variable	Result
Number of patients	99
Age (years), mean±SD	52.4±18.9
Gender, n (%)	
Female	58 (58.6)
Male	41 (41.4)
Diagnosis	
Oncology	78 (78.7)
Breast	51 (65.3)
Lung	12 (15.3)
Prostate	3 (4.2)
PNET	6 (7.6)
Others	6 (7.6)
Non-oncology	21 (21.3)
Total number of lesions	108

PNET, primitive neuroectodermal tumor

Table 2. Site and location of the evaluated lesions

	n (%)
Site	
Dorsal vertebrae	38 (35.1)
Lumbar vertebra	67 (62)
Sacrum	3 (2.9)
Location	
Vertebral body	76 (70.3)
Vertebral pedicle	4 (3.7)
Vertebral transverse process	4 (3.7)
Intervertebral facet joint	18 (16.8)
Vertebral spinous process	4 (3.7)
Vertebral endplate	1 (0.9)
Contamination	1 (0.9)

Table 3. Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of planar scintigraphy, SPECT, CT, and SPECT-CT in diagnosing metastases among the lesions evaluated

Parameter	Planar scintigraphy	SPECT	CT	SPECT-CT
Sensitivity (%)	100 (87.6–100)	82.1 (63.1–93.9)	89.2 (71.7–97.7)	92.8 (76.5–99.1)
Specificity (%)	36.2 (25.7–47.7)	87.5 (78.2–93.8)	100 (95.4–100)	100 (95.4–100)
Positive predictive value (%)	35.4 (25–47)	69.7 (51.2–84.4)	100 (86.2–100)	100 (86.7–100)
Negative predictive value (%)	100 (88–100)	93.3 (51.2–84.4)	96.3 (89.8–99.2)	97.5 (91.4–99.7)
Accuracy (%)	52.7	86.1	97.2	98.1

CT, computed tomography; SPECT, single photon emission tomography.
Data in parentheses represent 95% confidence interval.

Table 4. Results of receiver operating characteristic (ROC) analysis

Modality	Area under the curve	Standard error	95% confidence interval
Planar scintigraphy	0.747	0.049	0.654–0.826
SPECT	0.883	0.0319	0.806–0.937
CT	0.944	0.0207	0.883–0.979
SPECT-CT	0.964	0.0163	0.909–0.990

CT, computed tomography; SPECT, single photon emission tomography.

facet joint arthritis. SPECT-CT and CT showed the correct diagnosis for these lesions.

ROC analysis

The results of the ROC analysis are shown in Table 4 and Fig. 1. The AUC was largest for SPECT-CT followed by CT, SPECT, and planar scintigraphy. We compared the diagnostic accuracy of planar scintigraphy, SPECT, and SPECT-CT by comparing the AUC for each (Fig. 1). The diagnostic accuracy of SPECT was significantly higher than planar scintigraphy ($P = 0.012$). SPECT-CT performed better than both planar scintigraphy ($P < 0.001$) and SPECT alone ($P = 0.014$) but was not superior to CT ($P = 0.302$) (Figs. 2–4). CT was superior to planar scintigraphy ($P < 0.001$) but only slightly superior to SPECT ($P = 0.063$).

Impact on management

As these vertebral lesions were the only lesions in these patients, their management was dependent on characterization of these lesions. SPECT-CT correctly characterized 96% (47/49) of the equivocal lesions observed by

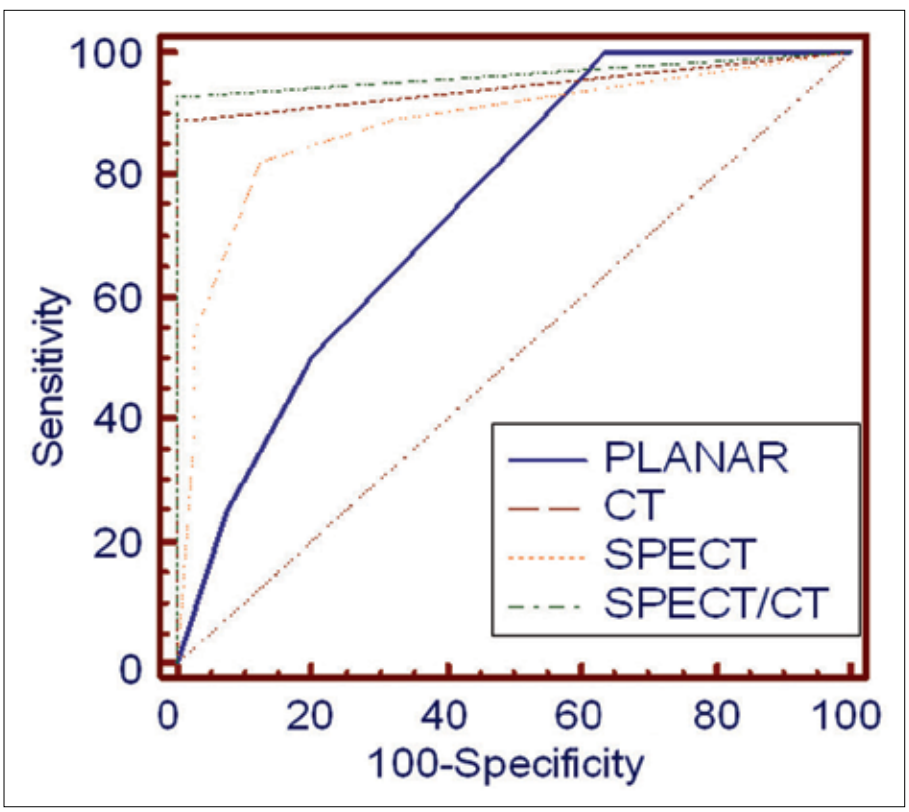

Figure 1. A receiver operating characteristic curve showing the area under the curve for planar scintigraphy, SPECT, CT, and SPECT-CT. The area under the curve was greatest for SPECT-CT followed by CT, SPECT and planar scintigraphy.

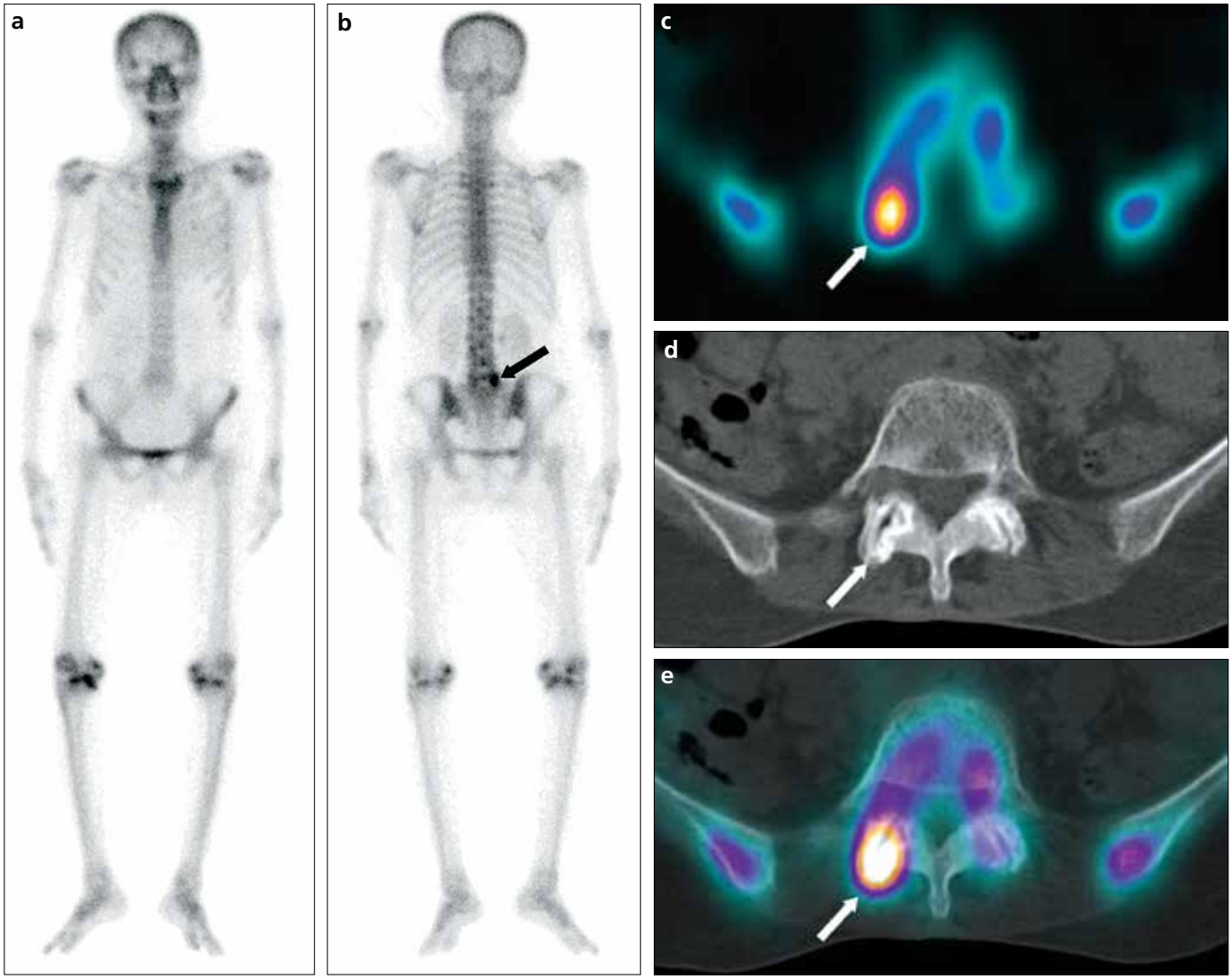

Figure 2. a–e. A 59-year-old female patient had therapy for carcinoma of the right breast. She presented with back pain. Bone scintigraphy was performed to rule out bone metastasis. Planar bone scintigraphy images **(a, b)** show focal uptake in the L5 vertebra (*arrow;* score 3). Axial SPECT **(c)** image shows uptake in the region of right facet joint of the L5-S1 vertebrae (*arrow;* score 5). Axial CT **(d)** and SPECT-CT **(e)** images show L5-S1 vertebrae right facet joint arthritis with increased tracer uptake (*arrow;* score 5). On these images, SPECT, CT and SPECT-CT characterized the planar scintigraphy indeterminate lesion as benign.

planar scintigraphy. In addition, 16 definitely metastatic/most likely metastatic lesions identified on planar scintigraphy were correctly characterized as benign by SPECT-CT. SPECT-CT correctly characterized 81.2% (13/16) indeterminate lesions observed by SPECT. Additionally, two definitely metastatic/most likely metastatic lesions on SPECT were correctly characterized as benign and four definitely benign/most likely benign lesions on SPECT were correctly characterized as metastatic by SPECT-CT. Thus, SPECT-CT had an impact on the clinical management of 60.6% patients (60 patients with 63 lesions) compared to planar scintigraphy, which only worked for 18.1% of the patients (18 patients with 19 lesions) compared to SPECT.

CT correctly characterized 85.7% (42/49) of the indeterminate lesions observed by planar scintigraphy. Additionally, 15 definitely metastatic/most likely metastatic lesions on planar scintigraphy were correctly characterized as benign by CT imaging. Thus, CT had an impact on the clinical management of 55 patients (with 57 lesions). CT correctly characterized 62.5% (10/16) of the indeterminate lesions observed by SPECT. Additionally, two definitely metastatic/most likely metastatic lesions on SPECT were correctly characterized as benign, and three definitely benign/most likely benign lesions on SPECT were correctly characterized as metastatic on CT. Thus, CT had an impact on the clinical management of 55.5% patients (55 patients with 57 lesions) compared to planar scintigraphy and 14.1% patients (14 patients with 15 lesions) compared to SPECT.

Discussion

Spinal lesions identified by bone scintigraphy are detected in a large number of patients. They can be caused by a wide variety of benign and malignant diseases. The specificity of planar bone scintigraphy for the characterization of spinal lesions is limited. In the present study, planar

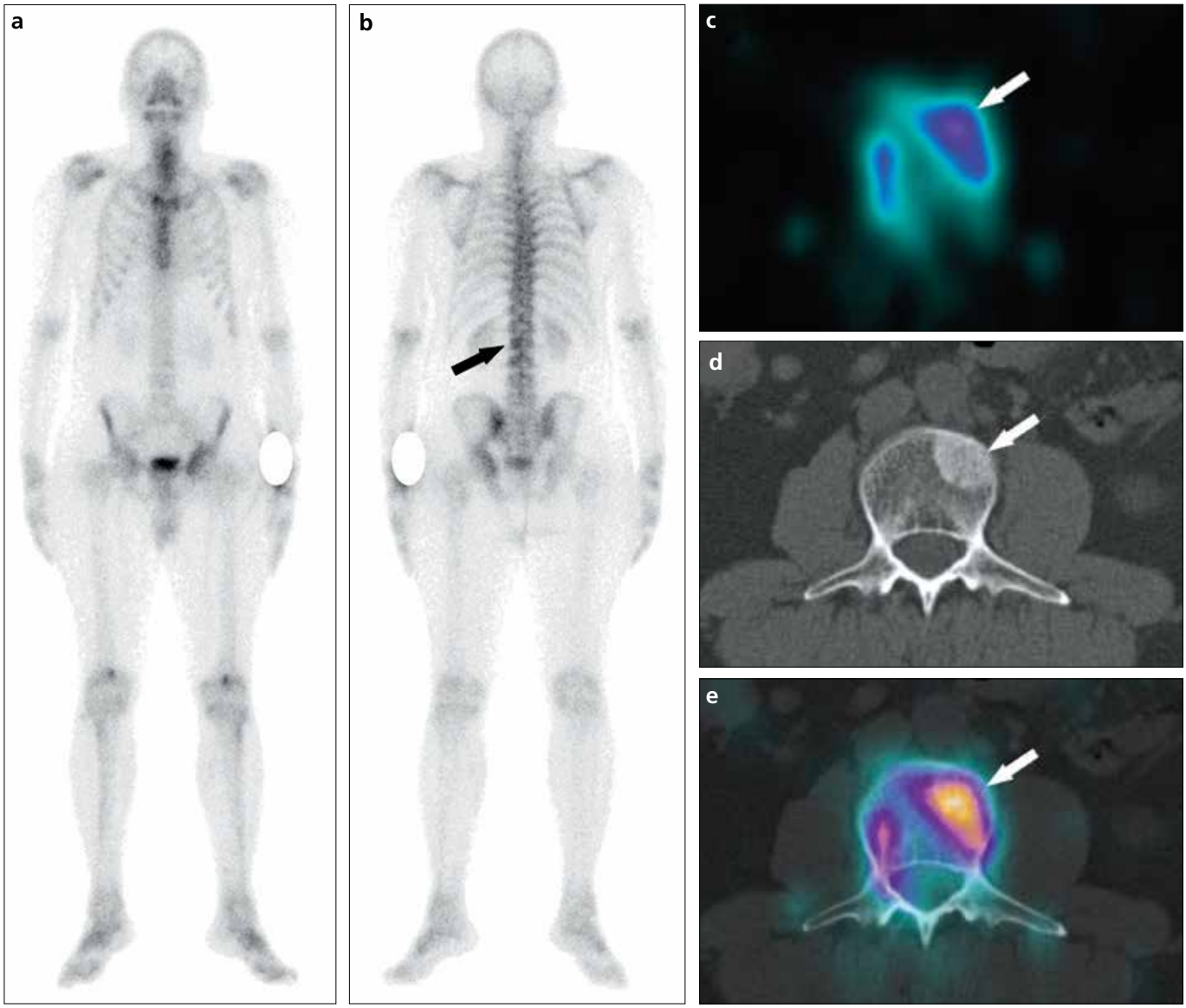

Figure 3. a–e. A 53-year-old male patient, a follow-up case of carcinoma of the prostate, presented with rising levels of the prostate specific antigen. Bone scintigraphy was performed to evaluate bone metastasis. Planar bone scintigraphy images **(a, b)** show faint focal uptake in the L2 vertebra (*arrow;* score 3). Axial SPECT **(c)** image shows uptake in the body of the L2 vertebra (*arrow;* score 2). Axial CT **(d)** and SPECT-CT **(e)** images show a sclerotic lesion in the body of the L2 vertebra with increased tracer uptake (*arrow;* score 1). On these images, SPECT, CT, and SPECT-CT characterized the planar scintigraphy indeterminate lesion as metastatic.

bone scintigraphy showed a specificity of only 36.2%. Additionally, 49 lesions (45.3%) remained indeterminate by planar bone scintigraphy imaging. As spinal lesions were the only lesions in our patient population, the management of these patients was dependent on accurate characterization of these lesions. Hence, it is important to further evaluate these lesions. The addition of SPECT improves the diagnostic accuracy of planar bone scintigraphy. It helps in accurate localization of the tracer activity in skeletal structures with complex anatomy, such as the spine (6). If a suspicious lesion identified by bone scintigraphy is localized to the pedicle or posterior aspect of the vertebral body by SPECT, it is more likely to be a metastasis (7). Moreover, using SPECT alone does not require additional radiation exposure to the patient, apart from that due to 99mTc-MDP administration. The specificity of SPECT in the present study was 87.5%. It was superior to planar bone scintigraphy for the characterization of spinal lesions (P = 0.012). However, 16 lesions still remained indeterminate on SPECT.

SPECT-CT combines the functional information of SPECT with the anatomical information of CT. Römer et al. (15) first evaluated the role of SPECT-CT for characterizing indeterminate bony lesions in patients with malignancy. SPECT-CT was able to clarify 90% such lesions in cancer patients. Only two studies in the literature have evaluated the utility of SPECT-CT for the characterization of vertebral lesions on bone scintigraphy. Zhang et al. (13) evaluated the role of SPECT-CT for isolated vertebral lesions on bone scintigraphy. Only 19.6%

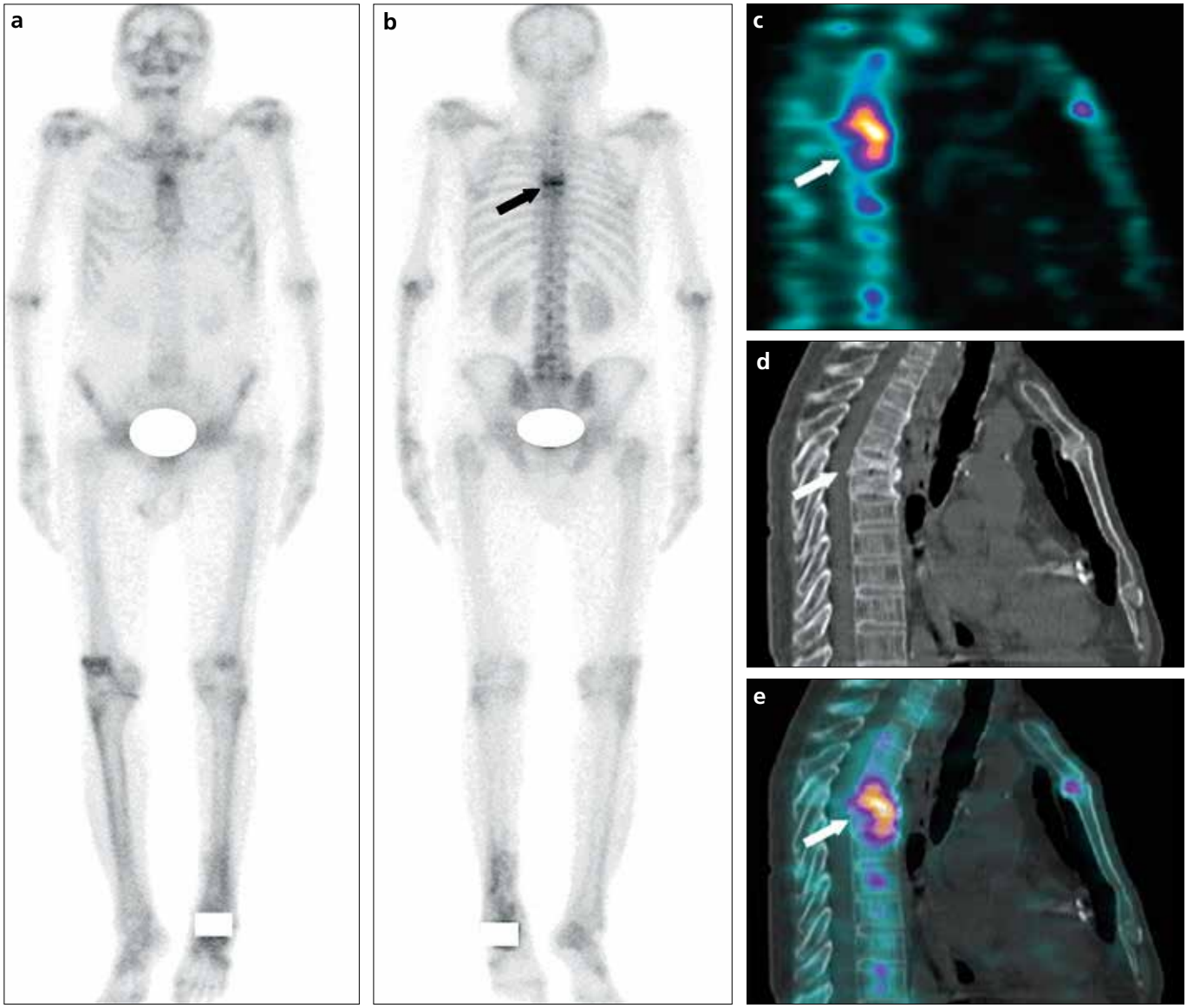

Figure 4. a–e. A 63-year-old male patient presented with multiple bone pain. Bone scintigraphy was performed to rule out bone metastasis. Planar bone scintigraphy images **(a, b)** show uptake in the T5 vertebra (*arrow;* score 2). Sagittal SPECT **(c)** image shows linear uptake in the body of the T5 vertebra (*arrow;* score 5). Sagittal CT **(d)** and SPECT-CT **(e)** images show the anterior wedge collapse of the T5 vertebra with increased tracer uptake (*arrow;* score 5). In these images, SPECT, CT, and SPECT-CT characterized the planar scintigraphy most likely metastatic lesion as benign.

lesions were categorized as equivocal on SPECT-CT compared to 67.9% lesions on SPECT alone. Another study by Iqbal et al. (12) also evaluated SPECT-CT for solitary vertebral lesions observed on bone scintigraphy. In their study, 13.8% of the lesions were indeterminate by baseline SPECT-CT imaging while none was indeterminate at follow-up SPECT-CT imaging. In the present study, only one lesion (1/108) was categorized as indeterminate on SPECT-CT. The relatively low number of indeterminate lesions can be attributed to the experience of the readers in evaluating musculoskeletal CT images (four and five years). Most of the lesions in the present study were located in the vertebral body (70.3%) followed by the facet joints (16.8%). Iqbal et al. (12) also reported similar findings. On comparison, SPECT-CT was superior to planar scintigraphy ($P < 0.001$) and SPECT ($P = 0.014$).

None of the studies in literature have compared CT alone with SPECT-CT for characterizing vertebral lesions observed on bone scintigraphy. We evaluated CT in this scenario and found it to be very accurate for this purpose. Only one lesion (1/108) was categorized as indeterminate by CT. The specificity of CT was similar to SPECT-CT (100%). Although CT was superior to planar scintigraphy ($P < 0.001$), it was only slightly superior to SPECT ($P = 0.063$). Interestingly, no significant difference was found between SPECT and SPECT-CT ($P = 0.302$). Given the wider availability and lesser acquisition time of CT compared to SPECT-CT, the former might be preferred especially in centers like ours that have a heavy patient load. However, the issue of additional radiation doses over and above that

due to SPECT alone should also be considered. In the present study, the additional radiation exposure due to CT was 3.1±1.2 mSv. This is almost similar to that due to bone scintigraphy alone, such that there is a 90%–100% increment in radiation dose (16). SPECT alone reduced the number of indeterminate lesions form 49 in planar scintigraphy to 16. Hence, only these 16 patients required additional CT when SPECT-CT is performed, while all patients will undergo CT if it is performed alone without SPECT. Hence, it seems rational that SPECT should be performed first, followed by CT imaging of only the lesions that remain indeterminate by SPECT imaging.

When evaluating the impact on management, we found that SPECT-CT correctly characterized 96% of the indeterminate lesions observed on planar scintigraphy and 81.2% of the indeterminate lesions observed on SPECT. In addition, 16 definitely metastatic/most likely metastatic lesions on planar scintigraphy were correctly characterized as benign by SPECT-CT imaging. SPECT-CT had an impact on the clinical management of 60.6% of patients compared to planar bone scintigraphy and 18.1% of patients compared to SPECT. In comparison, CT had an impact on the clinical management of 55.5% of patients compared to planar scintigraphy and 14.1% of patients compared to SPECT.

The present study had certain limitations. First, this was a retrospective analysis. Second, the histopathological diagnosis was not available for all lesions, and imaging was the mainstay of confirming the diagnosis. Although this is not ideal, it is acceptable given the difficulties and ethical issues associated with bone biopsy. Further prospective studies addressing these shortcomings and comparing SPECT-CT with other modalities such as 18-fluorodeoxyglucose positron emission tomography-computed tomography (PET-CT) and 18-fluoride PET-CT are warranted.

In conclusion, hybrid SPECT-CT is superior to planar bone scintigraphy and SPECT for characterizing spinal lesions observed by 99mTc-MDP bone scintigraphy. SPECT-CT can have significant impact on the management of these patients. However, it provides no significant added advantage over CT alone for this purpose.

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

1. Disibio G, French SW. Metastatic patterns of cancer: results from a large autopsy study. Arch Pathol Lab Med 2008; 132:931–939.
2. Boxer DI, Todd CE, Coleman R, Fogelman I. Bone secondaries in breast cancer: the solitary metastasis. J Nucl Med 1989; 30:1318–1320.
3. Hamaoka T, Madewell JE, Podoloff DA, Hortobagyi GN, Ueno NT. Bone imaging in metastatic breast cancer. J Clin Oncol 2005; 22:2924–2953
4. Rybak LD, Rosenthal DI. Radiological imaging for the diagnosis of bone metastases. Q J Nucl Med 2001; 45:53–64
5. Kobayashi K, Okuyama C, Kubota T, Nakai T, Ushijima Y, Nishimura T. Do short-time SPECT images of bone scintigraphy improve the diagnostic value in the evaluation of solitary lesions in the thoracic spine in patients with extraskeletal malignancies? Ann Nucl Med 2005; 19:557–566.
6. Horger M, Bares R. The role of single photon emission computed tomography/computed tomography in benign and malignant bone disease. Semin Nucl Med 2006; 36:286–294.
7. Love C, Din AS, Tomas MB, Kalapparambath TP, Palestro CJ. Radionuclide bone imaging: an illustrative review. Radiographics 2003; 23:341–358.
8. Reinartz P, Schaffeldt J, Sabri O, Zimny M, Nowak B, Ostwald E. Benign versus malignant osseous lesions in the lumbar vertebrae: differentiation by means of bone SPECT. Eur J Nucl Med 2000; 27:721–726.
9. Bocher M, Balan A, Krausz Y, Shrem Y, Lonn A, Wilk M. Gamma camera-mounted anatomical x-ray tomography: technology, system characteristics and first images. Eur J Nucl Med 2000; 27:619–627.
10. Townsend DW, Cherry SR. Combining anatomy and function: the path to true image fusion. Eur Radiol 2001; 11:1968–1974.
11. Schillaci O, Danieli R, Manni C, Simonetti G. Is SPECT/CT with a hybrid camera useful to improve scintigraphic imaging interpretation? Nucl Med Commun 2004; 25:705–710.
12. Iqbal B, Currie GM, Wheat JM, Raza H, Kiat H. The incremental value of SPECT/CT in characterizing solitary spine lesions. J Nucl Med Technol 2011; 39:201–207.
13. Zhang Y, Shi H, Gu Y, et al. Differential diagnostic value of single-photon emission computed tomography/spiral computed tomography with Tc-99m-methylene diphosphonate in patients with spinal lesions. Nucl Med Commun 2011; 32:1194–1200.
14. Even-Sapir E, Metser U, Flusser G, Zuriel L, Kollender Y, Lerman H. Assessment of malignant skeletal disease: initial experience with 18F-fluoride PET/CT and comparison between18F-fluoride PET and 18F-fluoride PET/CT. J Nucl Med 2004; 45:272–278.
15. Römer W, Nömayr A, Uder M, Bautz W, Kuwert T. SPECT-guided CT for evaluating foci of increased bone metabolism classified as indeterminate on SPECT in cancer patients. J Nucl Med 2006; 47:1102–1106.
16. Radiation dose to patients from radiopharmaceuticals (Addendum 2 to ICRP publication 53). ICRP publication 80 approved by the commission in September 1997. Ann ICRP 1998; 28:1–126.