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# SPECT-Guided CT for Evaluating Foci of Increased Bone Metabolism Classified as Indeterminate on SPECT in Cancer Patients

Wolfgang Römer<sup>1</sup>, Anton Nömayr<sup>1</sup>, Michael Uder<sup>2</sup>, Werner Bautz<sup>2</sup>, and Torsten Kuwert<sup>1</sup>

<sup>1</sup>*Clinic of Nuclear Medicine, University of Erlangen-Nuremberg, Erlangen, Germany; and* <sup>2</sup>*Institute of Radiology, University of Erlangen-Nuremberg, Erlangen, Germany*

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Hybrid cameras combining SPECT and spiral CT offer the opportunity to obtain a diagnostic-quality CT image of scintigraphically suggestive lesions that directly correlates with the SPECT image. The field of view of the CT scan can be adapted on the basis of the SPECT findings ("SPECT-guided CT"). The aim of the present study was to investigate the value of SPECT-guided CT in the assessment of foci of increased bone metabolism classified as indeterminate on SPECT. **Methods:** Of 272 consecutively examined patients with histologically confirmed malignancy who underwent bone scintigraphy, 112 (41%) required further workup by SPECT because a definite diagnosis could not be established using whole-body planar scintigraphy alone. In 57 of these patients, SPECT was accompanied by inline CT over the body region of interest; the remaining 55 subjects underwent only stand-alone SPECT for logistic reasons. The 57 SPECT/CT studies were retrospectively evaluated by readers who were unaware of the clinical pretest probability and the findings on the planar scans. In total, 52 lesions in 44 patients were rated as indeterminate on the SPECT images. Afterwards, the corresponding SPECT/CT images were analyzed and the findings previously rated as indeterminate were classified either as definitely benign, indeterminate, or definitely malignant. **Results:** Of the 52 indeterminate findings on SPECT, 33 (63%) could be correlated with benign findings on CT. These findings involved mostly osteochondrosis, spondylosis, and spondylarthrosis of the spine. Fifteen lesions (29%) could be correlated with osteolysis or sclerotic metastases on CT. Even after analysis of the SPECT/CT images, 4 lesions (8%) remained indeterminate. These lesions were in the ribs and the scapula. **Conclusion:** SPECT-guided CT was able to clarify more than 90% of SPECT findings classified as indeterminate in an analysis that was masked as to clinical pretest probability and the planar scan findings. Further studies carefully addressing the cost efficiency of this new technology and its actual clinical value are encouraged by this observation.

**Key Words:** SPECT/CT; spiral CT; hybrid imaging; SPECT-guided CT; bone scintigraphy

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Numerous reports emphasize the high sensitivity of bone scintigraphy in the diagnosis of osseous metastases (1). However, because benign lesions of the bone accumulate the <sup>99m</sup>Tc-labeled diphosphonates as well, the specificity of bone scintigraphy is quite low (2). A particular problem is the enhanced diphosphonate uptake in degenerative processes. In most cases, this enhancement affects the vertebral column and the pelvis. Especially difficult is the differentiation of deforming spondylosis and spondylarthrosis, that is, degenerative disease of the facets, from metastases. In planar scintigraphy, superimposition hampers the exact anatomic localization of lesions. The addition of SPECT allows better distinction of benign from malignant changes because of the more exact localization of increased diphosphonate uptake (3–5). However, the specificity of SPECT is also not sufficient for a reliable diagnosis (6).

In daily clinical routine, additional radiologic procedures are recommended for cases of focally enhanced diphosphonate uptake. As a first step, planar radiographs usually are obtained. If these show clear signs of arthrosis, it is concluded that the scintigraphic abnormalities are benign. If osteolysis is clearly shown, CT may be indicated to assess bone stability. However, if the radiographic findings are unremarkable, further tests, particularly MRI, are necessary. These may be time consuming and may delay therapeutic procedures; furthermore, they cause considerable stress to the patients waiting for the diagnosis.

In recent years, a hybrid camera combining a dual-head SPECT camera with a low-dose nondiagnostic CT scanner has been commercially available (7,8). However, more recently, hybrid cameras combining SPECT and spiral CT have offered the opportunity to perform diagnostically sufficient CT of scintigraphically suggestive lesions in a single session. These systems allow the field of view of the CT scan to be adapted to the SPECT findings ("SPECT-guided CT").

The aim of the present study was to analyze—with masking of clinical pretest probability and planar scan findings—the value of SPECT-guided CT in the evaluation of spinal, thoracic, or pelvic foci of increased bone metabolism that

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For correspondence or reprints contact: Wolfgang Römer, MD, Clinic of Nuclear Medicine, University of Erlangen-Nürnberg, Krankenhausstrasse 12, D-91054 Erlangen, Germany.

E-mail: wolfgang.roemer@nuklear.imed.uni-erlangen.de

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had been classified as indeterminate on SPECT. Only cancer patients were included in the study.

## MATERIALS AND METHODS

### Selection of Patients

From March 2005 until July 2005, 272 patients with histologically confirmed malignancy underwent bone scintigraphy in the Clinic of Nuclear Medicine of the University of Erlangen/Nürnberg. For bone scintigraphy, the patients received  $^{99m}\text{Tc}$ -dicarboxypropane diphosphonate intravenously (mean dose, 735 MBq; range, 589–842 MBq). Planar whole-body scintigraphy was performed 3 h after injection. Immediately after acquisition, these images were analyzed by a board-certified nuclear medicine physician, who determined whether further workup by SPECT or SPECT/CT was needed. In 160 of the patients, a definite diagnosis could be established using whole-body planar scintigraphy alone. In the remaining 112 patients (41%), further workup by SPECT was necessary because of unclear findings on the whole-body planar scintigraphy. In 57 of these patients, a SPECT/CT scan was acquired using a hybrid camera combining a dual-head  $\gamma$ -camera with a dual-slice spiral CT scanner installed within the same gantry (Symbia T2; Siemens Medical Solutions) (9); in the other 55 subjects, SPECT alone was performed, mainly because of the temporary unavailability of the SPECT/CT system or for other logistic reasons. The 57 SPECT/CT studies were retrospectively evaluated by readers who were unaware of clinical pretest probability and the findings on the planar scans.

The design of the present study was retrospective and explorative. The patient data used had been acquired solely for clinical and not for scientific reasons.

### SPECT/CT Acquisition

The SPECT scan was acquired first, with the equivocal finding included in the center of the field of view. When more than 1 unclear finding was detected on the planar whole-body scan, the field of view was positioned so as to include all findings. In 2 patients, a second SPECT/CT scan after completion of the first was necessary to visualize all lesions under study. Immediately after the SPECT data had been acquired, the raw data were reconstructed into transaxial, coronal, and sagittal slices using e.soft reconstruction software (Siemens Medical Solutions). The resulting SPECT images were analyzed by a physician not to decide on the necessity of CT but to define the field of view for the CT. Exposure to radiation was reduced by restricting the field of view for CT to the area of the indeterminate SPECT findings. For this aim, a CT topogram was acquired and the scan area for CT was planned using the anatomic information from the SPECT images. Afterward, the CT scan was acquired. Both SPECT and CT were performed during shallow breathing, with the patients stably lying supine. The interval between SPECT and CT was less than 3 min.

For the SPECT acquisition, counts from the 15% energy windows at 140 keV were acquired into a  $128 \times 128$  matrix (pixel size,  $4.6 \times 4.6$  mm). Sixty-four 30-s frames were acquired over  $360^\circ$ . The camera heads were equipped with a high-resolution low-energy parallel-hole collimator. Reconstruction was performed iteratively using 3-dimensional (3D) ordered-subsets expectation maximization with 4 iterations and 8 subsets. Images were smoothed with a 3D spatial gaussian filter (10 mm in full width at half maximum).

The CT parameters included 130 kV, a 0.8-s rotation time, and a  $2 \times 2.5$  mm collimation. Because only bone structures required analysis, the tube current was reduced to 40 mAs to minimize radiation exposure. A recent study has shown that low-dose CT protocols are appropriate for the diagnosis of lytic bone changes (10). Image reconstruction using a high-resolution reconstruction algorithm (B80 kernel) resulted in images with a slice thickness of 3 mm for a 1.5-mm reconstruction increment.

For all fused images, the accuracy of the matching of internal anatomic landmarks visible on both CT and SPECT was checked; no misregistration exceeding 3 mm was noticed. Because the SPECT and CT data were optimally registered, Hounsfield units could easily be used to calculate attenuation coefficients, and attenuation-corrected images were reconstructed as described recently (11).

### Image Data Analysis

The attenuation-corrected SPECT scans of the 57 patients on whom SPECT/CT had been performed were reviewed independently of the clinical data and CT findings by 2 physicians who localized and classified every visible lesion according to a 3-point scale: 1, definitely benign; 2, indeterminate; 3, definitely malignant. In cases of discrepancy, consensus was obtained by a second joint reading.

Of 125 visible lesions, 52 were classified as indeterminate. These indeterminate SPECT findings were restricted to 44 patients: 10 men and 34 women with a mean age ( $\pm$ SD) of  $66 \pm 13.1$  y (range, 15–88 y). The predominant malignancies were breast and lung cancer (Table 1).

Four weeks after initial evaluation of the SPECT images, the fused SPECT/CT scans were evaluated by the same physicians in consensus. The findings previously rated as indeterminate were then reassessed according to the identical 3-point scale used for SPECT evaluation. On CT, 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 of benignity (12). SPECT/CT scans were reviewed interactively at a viewing station in 3D-scroll-through mode using a commercially available 3D-volume-fusion tool. The CT scans were displayed at the bone window settings (level, 500 HU; width, 2,000 HU). The color scale of the SPECT scans could be manipulated by the readers. The registered images were read in

**TABLE 1**  
Type and Incidence of Malignant Disease Within Study Group

Type of malignancy	No. of patients
Breast cancer	25
Lung cancer	5
Bladder cancer	2
Renal cancer	2
Rectosigmoidal cancer	2
Other*	8

\*Prostate cancer, Ewing sarcoma, thyroid cancer, synovial carcinoma, lymphoma, oropharyngeal cancer, squamous cell carcinoma with unknown primary, or carcinoma of unknown primary.

3D mode with the ability to change the ratio of CT and SPECT (% scale).

### Dose Assessment

CT-Expo software (Hannover Medical School) was used to determine the additional radiation exposure caused by the CT scan (13,14).

### RESULTS

A total of 52 lesions detected on the SPECT images of 44 patients were judged as indeterminate. The locations of these findings are listed in Table 2. Of the 52 indeterminate lesions, 33 (63%) could be correlated with benign findings on CT. These findings included mostly osteochondrosis (Fig. 1), spondylosis, and spondylarthrosis of the spine. Fifteen (29%) lesions could be correlated with osteolysis (Fig. 2) or sclerotic metastases on CT. Even after analysis of SPECT/CT, 4 lesions (8%) remained indeterminate.

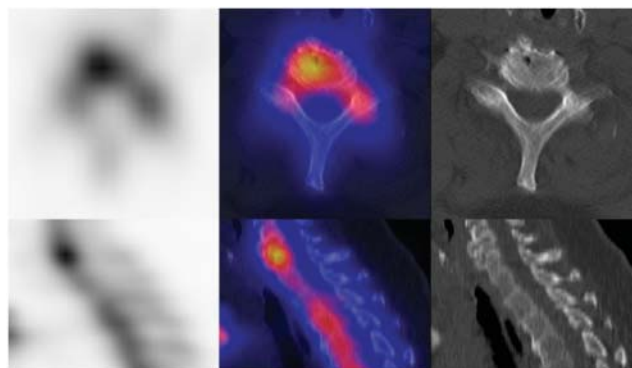
In Table 3, the numbers of findings classified as definitely benign, indeterminate, and definitely malignant on SPECT/CT are indicated for each anatomic region. The lesions that remained indeterminate even after correlation with the CT findings were in the scapula (in 2 patients) and in a rib (in another 2 patients). For all findings in the remaining anatomic regions, a definitive diagnosis could be made by combined analysis of SPECT and CT.

The additional radiation exposure due to the SPECT-guided CT was  $2.3 \pm 1.7$  mSv.

### DISCUSSION

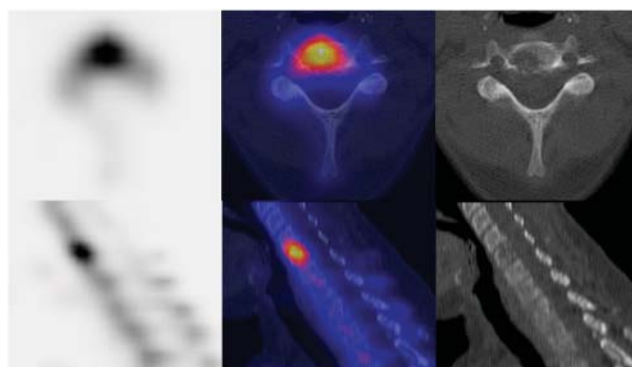
The development of SPECT/CT has been popularized by the recent implementation of spiral CT scanners. These systems can adapt the field of view of the CT scan to the SPECT findings. To the best of our knowledge, this is the first report on the value of SPECT-guided spiral CT in bone scintigraphy. In our group of patients, SPECT-guided CT allowed for a definite diagnosis in 92% of axial skeleton lesions classified as indeterminate on SPECT alone, thus considerably shortening the diagnostic process.

Up to now, the next step in the diagnostic workup of indeterminate findings on bone scintigraphy has been planar



**FIGURE 1.**  $^{99m}\text{Tc}$ -Dicarboxypropane diphosphonate SPECT/CT was performed with CT field of view from C4 to T4 in 74-y-old woman with breast cancer. SPECT images (left) show focally increased bone metabolism localized in vertebral body of C6. CT (right) discloses osteochondrosis in C6–C7, with vacuum phenomenon clearly matched to area of increased bone metabolism seen on fused images (middle). No osteolysis is detectable on CT. Top row is axial slices; bottom row, sagittal slices.

radiography, the least expensive and most widely available morphologic imaging modality (1). However, the drawbacks of planar radiography in the identification of osteolysis, especially in the spine, are well known (15). Clear evidence exists that destruction of more than 50% of trabecular bone is a prerequisite for metastases to be visible on planar radiography studies (16). Therefore, additional MRI or CT will be necessary to clarify enhanced bone metabolism in a considerable number of patients. A further problem is the difficulty and potential inaccuracy of correlating skeletal SPECT scans and planar radiographs through side-by-side viewing. Accuracy might be improved by using CT or MR images for side-by-side viewing or even by using retrospective registration with SPECT. In a recent publication, Utsunomiya



**FIGURE 2.**  $^{99m}\text{Tc}$ -Dicarboxypropane diphosphonate SPECT/CT was performed with CT field of view from C3 to T3 in 44-y-old woman with breast cancer. SPECT images (left) show focally increased bone metabolism localized in vertebral body of C5. CT (right) discloses clear-cut osteolysis in vertebral body of C5, with destruction of posterior corticalis clearly matched to area of increased bone metabolism seen on fused images (middle). No degenerative lesion is detectable on CT. Top row is axial slices; bottom row, sagittal slices.

**TABLE 2**

Anatomic Regions Exhibiting Indeterminate Findings on SPECT

Anatomic region	n	%
Cervical spine	11	21.2
Thoracic spine	12	23.1
Lumbar spine	10	19.2
Pelvis	6	11.5
Rib	8	15.4
Scapula	2	3.8
Sternoclavicular joint	1	1.9
Sternum	1	1.9
Clavicula	1	1.9

**TABLE 3**  
SPECT/CT Classification of Originally Indeterminate Findings

Anatomic region	Benign (n)	Indeterminate (n)	Malignant (n)
Cervical spine	10	0	1
Thoracic spine	7	0	5
Lumbar spine	7	0	3
Pelvis	4	0	2
Rib	4	2	2
Scapula	1	0	0
Sternoclavicular joint	1	0	0
Sternum	0	0	1
Clavicula	0	0	1

et al. (17) compared SPECT/CT fusion and side-by-side reading of SPECT and CT data. This group used an approach different from ours for the acquisition of registered bone SPECT and CT images: A gantry-free SPECT scanner and an 8-detector-row CT scanner were juxtaposed such that the CT table could move with the patient directly from the CT scanner into the SPECT scanner. Afterward, both image datasets were retrospectively registered on a separate workstation. Using this approach, the authors found that diagnostic confidence in differentiating malignant from benign bone lesions was better with the fused SPECT/CT images than with separate sets of bone scintigraphic and CT images. Also, our data showed that, at least in some patients, the exact match provided only by SPECT/CT might be necessary to exactly localize the area of increased tracer uptake, especially in small anatomic structures. This was the case in one of our patients in whom osteolysis was medially located only a few millimeters from the facet joint in the lamina and in whom the increased bone metabolism was caused by the osteolysis and not by degeneration of the facet (9).

Hybrid cameras combining SPECT with low-dose CT (140 kV, 2.5 mA) were introduced 5 years ago (7,18). This method, called transmission emission tomography (19), readily acquires data for attenuation correction and for identifying anatomic landmarks. However, because of the technical shortcomings of low-dose CT, morphology cannot be visualized in greater detail with this technology. Nevertheless, Horger et al. (8) could correctly classify 85% of unclear foci of diphosphonate uptake with transmission emission tomography, compared with only 36% using SPECT alone, agreeing with our data. They reported that the highest diagnostic gain was in the spine, the thorax, and the pelvis. However, they also conceded that, because of the limited resolution of the low-dose CT scan, small osteolytic lesions could be missed by transmission emission tomography. This shortcoming apparently does not apply to hybrid cameras equipped with spiral CT scanners, which achieve significantly higher resolution of morphologic detail.

In the protocol of the present study, CT was performed after SPECT. The SPECT images were evaluated while the patient was still in the scanner. The information from both

SPECT and planar scintigraphy was used to determine the area (limited to the suggestive focus of diphosphonate uptake) to be scanned additionally with CT. With this approach, the additional radiation exposure to the patient could be kept as low as possible. The mean radiation exposure caused by the SPECT-guided CT was 2.3 mSv, which is about one third the radiation exposure caused by the bone scintigraphy alone. This concept is in contrast to PET/CT, for which the fields of view of the PET and CT scans are identical in order to use CT data for attenuation correction (20). However, in PET, attenuation correction is mandatory. In SPECT, attenuation correction by the use of CT data is possible (11,21), but the clinical benefit of attenuation correction has not yet been sufficiently evaluated.

A possible limitation of the present study was the lack of an independent gold standard. However, 63% of the lesions seen on SPECT had clear-cut benign correlates on CT, including osteophytes, spondylophytes, subchondral sclerosis, or narrowing of the joint space. Alternatively, 29% were regarded as definitely malignant, with concordant clear-cut signs of malignancy on CT. These included osteolytic defects and sclerotic lesions. In our opinion, the origin of these lesions had been clarified sufficiently by 2 established imaging modalities and further evaluation would have been redundant. In a recent review article (15), Even-Sapir highlighted the advantages of CT in the evaluation of malignant bone involvement. The only limitation of CT is in the assessment of bone marrow infiltration, which may also escape detection by bone scintigraphy. Future work should therefore also be directed at comparing MRI and SPECT/CT for staging. Nevertheless, in the present study, only 8% of the lesions seen on SPECT remained unclear because of the lack of visible definite morphologic alterations on CT. Only for these cases would an independent gold standard have been necessary. However, because these lesions were in the ribs and scapula—a region in which respiratory movements cause MRI artifacts—confirmation or exclusion of metastases would not have been possible even with MRI. On the other hand, because of the limited size and unfavorable location of the indeterminate lesions, biopsy was not possible.

The results presented here do not allow conclusions to be drawn on how many patients referred for staging by bone scintigraphy would benefit from additional CT images registered to the SPECT images. To clarify this issue, the percentage of patients for whom the new technology leads to a change in diagnosis and subsequent therapy would have to be determined. As also highlighted in the selection process of the patients included in this study, 41% of the patients referred to our clinic for staging by bone scintigraphy had also been studied using SPECT. Seventy-seven percent of the patients studied with SPECT/CT exhibited indeterminate lesions on SPECT, most of which could be further characterized by SPECT/CT. However, we did not analyze in how many patients SPECT/CT led to a change in diagnosis, because we analyzed our data only on a lesion-by-lesion basis. Clearly, in the clinical setting, the low

specificity of bone scintigraphy is strongly reduced by incorporating clinical information into the evaluation of bone scintigraphy findings and by using pattern recognition of the whole scan. Therefore, in daily practice, the number of indeterminate lesions may not be as high as in our group of patients, because the SPECT images of these patients were evaluated independently of their clinical data. Furthermore, the examination of a SPECT-indeterminate lesion by additional CT may not always have a therapeutic impact—for example, when, in the same patient, clear-cut osseous metastases are also identifiable on the planar images. In our opinion, larger, ideally prospective studies would be needed to clarify these issues and those related to the cost efficiency of the new hybrid technology. These studies should also compare the value of SPECT/CT with that of other modalities, such as  $^{18}\text{F}$ -FDG PET,  $^{18}\text{F}$ -fluoride PET,  $^{18}\text{F}$ -choline PET, or whole-body MRI, in detecting osseous metastases (12,22,23).

## CONCLUSION

SPECT-guided CT is able to clarify more than 90% of SPECT findings classified as indeterminate in an analysis masked as to clinical pretest probability and planar scan findings. Further studies carefully addressing the cost efficiency of this new technology and its actual clinical value are encouraged by this observation.

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## REFERENCES

- Hamaoka T, Madewell JE, Podoloff DA, Hortobagyi GN, Ueno NT. Bone imaging in metastatic breast cancer. *J Clin Oncol*. 2004;22:2942–2953.
- Minoves M. Bone and joint sports injuries: the role of bone scintigraphy. *Nucl Med Commun*. 2003;24:3–10.
- Savelli G, Chiti A, Grasselli G, Maccauro M, Rodari M, Bombardieri E. The role of bone SPET study in diagnosis of single vertebral metastases. *Anticancer Res*. 2000;20:1115–1120.
- Even-Sapir E, Martin RH, Barnes DC, Pringle CR, Iles SE, Mitchell MJ. Role of SPECT in differentiating malignant from benign lesions in the lower thoracic and lumbar vertebrae. *Radiology*. 1993;187:193–198.
- Han LJ, Au-Yong TK, Tong WC, Chu KS, Szeto LT, Wong CP. Comparison of bone single-photon emission tomography and planar imaging in the detection of vertebral metastases in patients with back pain. *Eur J Nucl Med*. 1998;25:635–638.
- Reinartz P, Schaffeldt J, Sabri O, et al. Benign versus malignant osseous lesions in the lumbar vertebrae: differentiation by means of bone SPET. *Eur J Nucl Med*. 2000;27:721–726.
- 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.
- Horger M, Eschmann SM, Pfannenbergs C, et al. Evaluation of combined transmission and emission tomography for classification of skeletal lesions. *AJR*. 2004;183:655–661.
- Romer W, Beckmann MW, Forst R, Bautz W, Kuwert T. SPECT/spiral-CT hybrid imaging in unclear foci of increased bone metabolism: a case report. *Rontgenpraxis*. 2005;55:234–237.
- Horger M, Claussen CD, Bross-Bach U, et al. Whole-body low-dose multi-detector row-CT in the diagnosis of multiple myeloma: an alternative to conventional radiography. *Eur J Radiol*. 2005;54:289–297.
- Romer W, Fiedler E, Pavel M, et al. Attenuation correction of SPECT images based on separately performed CT: effect on the measurement of regional uptake values. *Nuklearmedizin*. 2005;44:20–28.
- Even-Sapir E, Metser U, Flusser G, et al. Assessment of malignant skeletal disease: initial experience with  $^{18}\text{F}$ -fluoride PET/CT and comparison between  $^{18}\text{F}$ -fluoride PET and  $^{18}\text{F}$ -fluoride PET/CT. *J Nucl Med*. 2004;45:272–278.
- Stamm G, Nagel HD. CT-Expo: a novel program for dose evaluation in CT [in German]. *Rofo*. 2002;174:1570–1576.
- Brix G, Lechel U, Veit R, et al. Assessment of a theoretical formalism for dose estimation in CT: an anthropomorphic phantom study. *Eur Radiol*. 2004;14:1275–1284.
- Even-Sapir E. Imaging of malignant bone involvement by morphologic, scintigraphic, and hybrid modalities. *J Nucl Med*. 2005;46:1356–1367.
- Rybak LD, Rosenthal DI. Radiological imaging for the diagnosis of bone metastases. *Q J Nucl Med*. 2001;45:53–64.
- Utsunomiya D, Shiraishi S, Imuta M, et al. Added value of SPECT/CT fusion in assessing suspected bone metastasis: comparison with scintigraphy alone and nonfused scintigraphy and CT. *Radiology*. 2006;238:264–271.
- Keidar Z, Israel O, Krausz Y. SPECT/CT in tumor imaging: technical aspects and clinical applications. *Semin Nucl Med*. 2003;33:205–218.
- Horger M, Eschmann SM, Lengerke C, Claussen CD, Pfannenbergs C, Bares R. Improved detection of splenosis in patients with haematological disorders: the role of combined transmission-emission tomography. *Eur J Nucl Med Mol Imaging*. 2003;30:316–319.
- Beyer T, Townsend DW, Brun T, et al. A combined PET/CT scanner for clinical oncology. *J Nucl Med*. 2000;41:1369–1379.
- Seo Y, Wong KH, Sun M, Franc BL, Hawkins RA, Hasegawa BH. Correction of photon attenuation and collimator response for a body-contouring SPECT/CT imaging system. *J Nucl Med*. 2005;46:868–877.
- Langsteger W, Heinisch M, Fogelman I. The role of fluorodeoxyglucose,  $^{18}\text{F}$ -dihydroxyphenylalanine,  $^{18}\text{F}$ -choline, and  $^{18}\text{F}$ -fluoride in bone imaging with emphasis on prostate and breast. *Semin Nucl Med*. 2006;36:73–92.
- Ghanem N, Uhl M, Brink I, et al. Diagnostic value of MRI in comparison to scintigraphy, PET, MS-CT and PET/CT for the detection of metastases of bone. *Eur J Radiol*. 2005;55:41–55.