Comparison of bone single-photon emission tomography and planar imaging in the detection of vertebral metastases in patients with back pain

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Abstract. Bone scan has long been considered to be an important diagnostic test in searching for bone metastases. However, considerable difficulty is encountered in the vertebral region due to the complexity of structures and the fact that other benign lesions, especially degenerative changes, are very common there. Single-photon emission tomography (SPET) has been reported to be useful in the differentiation of benign from malignant conditions. Here we report our experience with bone SPET in the diagnosis of vertebral metastases. This is a retrospective study of technetium-99m methylene diphosphonate (MDP) bone scans in 174 consecutive patients who were referred for the investigation of back pain in our department. MDP planar and SPET images were obtained. Of teh 174 patients, 98 had a known history of malignant tumours. The diagnosis of vertebral metastasis was made on the basis of the patients' clinical histories and the findings with other imaging techniques such as magnetic resonance imaging, computed tomography or follow-up bone scan. We found that the presence of pedicle involvement as seen on SPET was an accurate diagnostic criterion of vertebral metastasis. SPET had a sensitivity of 87%, a specificity of 91%, a positive predictive value of 82%, a negative predictive value of 94% and an accuracy of 90%. On the other hand, planar study had a sensitivity of 74%, a specificity of 81%, a positive predictive value of 64%, a negative predictive value of 88% and an accuracy of 79% in diagnosing vertebral metastasis. Except with regard to the negative predictive value, SPET performed statistically better than planar imaging. Only 9/147 (6.4%) lesions involving the vertebral body alone and 3/49 (6.1%) lesions involving facet joints alone were subsequently found to be metastases. We conclude that bone SPET is an accurate diagnostic test for the detection of vertebral metastases and is superior to planar imaging in this respect.

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Introduction

Bone scan is one of the commonest examinations performed in nuclear medicine. It is very sensitive in detecting osseous metastases; however, the uptake of diphosphonates is non-specific for bone metastasis since many benign bone lesions also demonstrate tracer uptake. Detection of one or more abnormal vertebrae at bone scintigraphy is a common finding in clinical practice, particularly in the elderly, who have a high incidence of benign changes in the vertebral column [1]. The differentiation between malignant and benign lesions is an important issue especially in patients with known metastases. In the spine, different disease processes involve different parts of the vertebrae [2]. The differentiation between these various possibilities depends on knowledge of the precise anatomical location of the lesion. Single-photon emission tomography (SPET) has been shown to be more sensitive than planar imaging in the detection of abnormalities, offering more precise localization of vertebral lesions [1]. The aims of this study were: (a) to determine whether SPET has a role in patients with back pain by providing diagnostic information that can be helpful in differentiating malignant from benign lesions, (b) to compare the diagnostic accuracy of planar imaging with that of SPET, and (c) to assess the predictive value of radionuclide bone imaging in the clinical setting.

Materials and methods

Patient population. We retrospectively reviewed SPET studies of the thoracolumbar spine obtained in 174 consecutive patients (78 males and 96 females) between February 1996 and June 1997. All

patients had been referred to our department for the investigation of back pain. They were recruited according to the following criteria: (a) patients without a known history of malignant tumour who were suffering from back pain, (b) patients with malignant disease who suffered from back pain but had no evidence of vertebral metastasis on plain X-ray. MDP bone scans were performed.

Patients were followed up by reviewing their clinical records. Vertebral metastases were considered to be present if clinical features and radiological findings including magnetic resonance imaging (MRI), computed tomography (CT) and follow-up bone scans showed definite evidence of metastasis. The MRI and CT studies had to be performed within 2 months of the bone scan, and the follow-up bone scan at least 4 months after the initial bone scan.

Scintigraphy. All patients underwent both planar and SPET studies on the same day. 740 MBq (20 mCi) of technetium-99m methylene diphosphonate (MDP) was injected intravenously. Planar imaging was performed 3 h later with a large field-of-view gamma camera (Elscint Helix or General Electrics XC/T) equipped with a high-resolution, low-energy, parallel-hole collimator. Single-pass (Elscint Helix) or double-pass (GE) whole-body imaging was performed with additional local views if necessary. SPET imaging of the spine was performed immediately after planar imaging. Data acquisition was performed with a 128×128 matrix and 3° per frame in a circular orbit. Transaxial, coronal and sagittal slices were reconstructed with a Butterworth filter of cutoff frequency 0.35 and power factor 5. Slice thickness was about 6.4 mm.

Bone scan interpretation. Three experienced nuclear medicine physicians interpreted images on film independently. Planar and SPET studies were interpreted separately. In SPET studies, vertebral metastasis was diagnosed if the pedicle showed increased uptake, regardless of whether there was vertebral body involvement. SPET studies were considered to show benign conditions if only the vertebral body or facet joints had increased MDP uptake. On planar images, the intensity of MDP uptake was classified as mild, moderate or marked. Those vertebral lesions showing a linear pattern of uptake were considered to be benign. All other patterns of uptake were considered to represent metastases. The results were analysed by the chi-square test. A P value of ≤0.05 was considered to be statistically significant.

Table 1. Summary of patients with known cancer

Malignancies	No. of patients
Prostate cancer	37
Breast cancer	17
Nasopharyngeal carcinoma	12
Bronchogenic carcinoma	11
Colon and rectal carcinoma	6
Renal cell carcinoma	5
Hepatocellular carcinoma	2
Stomach carcinoma	2
Lymphoma	2
Gynecological cancer	1
Thyroid cancer	1
Others	2

Table 2. Uptake patterns and the percentage of malignant and benign lesions

	Metastases	Benign lesions
Planar imaging	69	158
SPET	89	195
Body + pedicle	37 (84.0%)	7 (16.0%)
Pedicle	40 (80.0%)	10 (20.0%)
Body	9 (6.4%)	132 (93.6%)
Facet joint	53 (6.1%)	446(93.9%)

Table 3. Pattern of lesion uptake on planar images

	Lesion uptake pattern	
	Focal	Diffuse
Metastases (n = 69)	42 (60.9%)	27 (39.1%)
Benign (n = 158)	67 (42.4%)	91 (57.6%)

χ^2=6.56, P=0.0104

Results

The 174 patients recruited into the study had an age range of 23–95 years, with a mean age of 69 years. Seventy-six patients had low back pain and no known primary malignancy. Ninety-eight patients had a history of malignancy but no known skeletal metastases. The follow-up period ranged from 4 to 20 months (9.31±3.16 months, mean±1 SD). Table 1 summarizes the diagnoses of patients with cancer. There were 284 lesions in the thoracolumbar spine. All were detected by SPET, but 57 (20.1%) of them were not seen on planar images. Of the 284 lesions, 89 (31.3%) were metastases and 195 were benign bone lesions. On SPET, 50 lesions were seen to involve the pedicles only; 40 (80%) of these lesions were confirmed to be metastases. Forty-four lesions on SPET images showed both vertebral body and pedicle involvement; 30 (84%) of these were metastases. One hundred and forty-one lesions were located in vertebral bodies only, of which 132 (93.6%) were benign. Of the 49 lesions detected in the facet joints, 46 (93.9%) were benign. The pattern of uptake and the percentages of malignant and benign lesions are listed in Table 2. Table 3 shows the pattern of uptake on planar images and the diagnosis. Diffuse increased MDP uptake in the vertebral body was more commonly associated with benign lesions (57.6%), while focal uptake was more commonly associated with malignant lesions (60.9%). Although the relation between the pattern of uptake and the diagnosis was statistically significant, there was great overlap between these two patterns of uptake. Table 4 shows the intensity of uptake of the vertebral lesions on planar images and the incidence of malignancy; there was no correlation between the intensity of uptake on planar images and the nature of lesions.

In the current study, SPET was found to have a sensitivity of 87%, a specificity of 91%, an accuracy of 90%,

Table 4. Intensity of lesion uptake on planar images

	Intensityof lesion uptake		
	Mild	Moderate	Marked
Metastases (n = 69)	17	28	16
Benign (n = 158)	47	53	58

P>0.05

Table 5. Results of SPECT and planar imaging

	Planar	SPET	χ^2	P
Sensitivity (%)	74	87	4.01	0.0451
Specificity (%)	81	91	7.15	0.0075
Accuracy (%)	79	90	10.97	0.0009
Positive predictive value (%)	64	82	7.33	0.0068
Negative predictive value (%)	88	94	3.59	0.058

a positive predictive value of 82% and a negative predictive value of 94%. Planar imaging had a sensitivity of 74%, a specificity of 81%, an accuracy of 79%, a positive predictive value of 64% and a negative predictive value of 88% (Table 5). When analyzed by the chi square test, SPET performed better than planar imaging in terms of sensitivity, specificity, accuracy and positive predictive value. Although SPET had a higher negative predictive value than planar imaging, the difference was not statistically significant.

Nineteen vertebral metastases were diagnosed by SPET in those patients without known malignancy while only 12 were detected by planar imaging.

Discussion

SPET bone imaging has been advocated as an accurate and sensitive diagnostic tool in patients with low back pain [3] which offers advantages over planar techniques based on improved contrast enhancement. The three-dimensional imaging capability allows precise anatomical localization of an abnormality. This is important when evaluating patients with back pain because localization of a lesion in different vertebral parts significantly affects diagnostic possibilities.

Our results showed that 20.1% of abnormalities were not seen on planar images. SPET is likely to be beneficial in the case of abnormalities with less intense MDP uptake on the planar scan. In this study, bone SPET not only showed a much higher sensitivity than planar imaging for the detectin of metastatic foci (87% vs 74%), but also a much higher specificity (91% vs 81%). Involvement of the pedicle had a high predictive value in respect of vertebral metastasis, whereas uptake in the body or facet joint commonly represented benign lesions. These results correlate with previously documented findings that lesions causing abnormal uptake in the pedicle are usually malignant (83%), whereas focal or diffuse uptake in the body typically represents benign lesions (89%) [1].

Yuh et al. [5] found that MRI demonstration of an abnormal pedicle was seen more frequently in patients with metastases (88%); abnormalities involving the pedicle alone or the pedicle and the vertebral body were more likely to be malignant disease than abnormalities that involved only the vertebral body or facet joint. The predilection for posterior vertebral body involvement was believed by Gates [6] to be due to provision by the posteriorly located basivertebral vein of a route of hematogenous spread of metastases into the vertebra with early pedicle invasion and destruction. This pattern of tumour spread was the same for cervical, thoracic and lumbar vertebrae, although the frequency of tumour involvement was thought to be greater in the lumbar area. Therefore differentiation of benign from malignant disease in the SPET studies was largely dependent upon identifying the pedicle and then determining whether its uptake was abnormal. Some authors have suggested that bone SPET should become routine in patients with low back pain. Kamby et al. [7] have reported that the spread of tumour to bone marrow occurs before cortical destruction. MRI is probably the most sensitive imaging modality in diagnosing marrow metastasis, but has the limitation of not permitting whole body imaging. The widespread availability and ease of performance of bone scan make it the modality of choice for the diagnosis of vertebral metastases, to be supplemented by MRI when it proves inadequate in answering clinical questions [8]. In the current study, bone SPET detected all lesions seen on MRI. This is probably due to the referral pattern in our locality: patients were referred for bone scan when they complained of back pain, which may mean that the cortical bone had already been involved.

SPET has certain disadvantages such as the prolonged imaging time, which may lead to reduced patient throughput, and the potential for motion artefacts, which are a problem especially in patients who cannot cooperate [4]. Due to these drawbacks, some centres do not usually perform SPET. These problems, however, have been partially solved by the development of multihead gamma cameras, which greatly reduce the scanning time, thereby improving patient throughput and department workload considerably. Those departments that are unable to perform SPET may benefit from additional planar oblique views of the spine on which posterior elements, especially the facet joints, may be more easily identified [9]. Tondeur and Ham suggested that the diagnostic value of posterior 180° images is equivalent to that of 360° images, with a reduction in examination time and hence also in patient discomfort and motion artifacts [10]. This technique is particularly useful with single-head SPET cameras; its further evaluation and application may render SPET an easier procedure.

Although our study shows that SPET is valuable in the detection of vertebral metastases in the thoracolum-

bar region, it is difficult to perform in the cervical vertebrae since their smaller size and more compact structure make localization of the site of uptake difficult. Furthermore, the shoulders hinder close positioning of the camera head and impair the spatial resolution.

Conclusion

Both planar and SPET radionuclide imaging are excellent modalities for evaluating low back pain. SPET has better sensitivity, specificity, accuracy and positive predictive value than planar imaging. The high negative predictive value (0.94) and positive predictive value (0.82) of SPET, and its ability to localize lesions precisely, permit its use to determine whether abnormalities in patients with low back pain represent benign disease or metastases. The involvement of the pedicle is a reliable sign of metastasis. Vertebral SPET should be performed without hesitation when there is equivocal uptake in the vertebra on planar imaging and in patients with back pain despite normal planar imaging.

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