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FULL PAPER

Comparison of ^{18}F -fluoride PET/CT, ^{18}F -FDG PET/CT and bone scintigraphy (planar and SPECT) in detection of bone metastases of differentiated thyroid cancer: a pilot study

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Objective: We compared the efficacies of ^{18}F -fluoride positron emission tomography (^{18}F -fluoride PET)/CT, ^{18}F -fludeoxyglucose PET (^{18}F -FDG PET)/CT, and $^{99\text{m}}\text{Tc}$ bone scintigraphy [planar and single photon emission CT (SPECT)] for the detection of bone metastases in patients with differentiated thyroid carcinoma (DTC).

Methods: We examined 11 patients (8 females and 3 males; mean age $\pm$ standard deviation, 61.9 ± 8.7 years) with DTC who had been suspected of having bone metastases after total thyroidectomy and were hospitalized to be given ^{131}I therapy. Bone metastases were verified either when positive findings were obtained on both ^{131}I scintigraphy and CT or when MRI findings were positive if MRI was performed.

Results: Metastases were confirmed in 24 (13.6%) of 176 bone segments in 9 (81.8%) of the 11 patients. The sensitivities of ^{18}F -fluoride PET/CT and $^{99\text{m}}\text{Tc}$ bone scintigraphy (SPECT)

were significantly higher than those of ^{18}F -FDG PET/CT and $^{99\text{m}}\text{Tc}$ bone scintigraphy (planar) ($p < 0.05$). The accuracies of ^{18}F -fluoride PET/CT and $^{99\text{m}}\text{Tc}$ bone scintigraphy (SPECT) were significantly higher than that of $^{99\text{m}}\text{Tc}$ bone scintigraphy (planar) ($p < 0.05$).

Conclusion: The sensitivity and accuracy of ^{18}F -fluoride PET/CT for the detection of bone metastases of DTC are significantly higher than those of $^{99\text{m}}\text{Tc}$ bone scintigraphy (planar). However, the sensitivity and accuracy of $^{99\text{m}}\text{Tc}$ bone scintigraphy (planar) are improved near to those of ^{18}F -fluoride PET/CT when SPECT is added to a planar scan. The sensitivity of ^{18}F -FDG PET/CT is significantly lower than that of ^{18}F -fluoride PET/CT or $^{99\text{m}}\text{Tc}$ bone scintigraphy (SPECT).

Advances in knowledge: This article has demonstrated first the high efficacy of ^{18}F -fluoride PET/CT for the detection of bone metastases of DTC.

Differentiated thyroid carcinoma (DTC) shows a relatively good prognosis compared with carcinomas of other organs, and the 10-year survival rate of DTC is $>80\%$ because of treatments such as total thyroidectomy and ablation of remnants with radioiodine.¹ However, metastases of DTC develop in 7–23% of patients; the distant metastases occur commonly in the lungs, bones and brain, and the bones are the second most common site of metastases of DTC.² Bone scintigraphy using $^{99\text{m}}\text{Tc}$ -labelled phosphate compounds [$^{99\text{m}}\text{Tc}$ -methylene diphosphonate ($^{99\text{m}}\text{Tc}$ -MDP) or $^{99\text{m}}\text{Tc}$ -hydroxymethylene diphosphonate ($^{99\text{m}}\text{Tc}$ -HMDP)] has been widely used for detecting and evaluating bone metastases of various kinds of carcinomas because of its overall high sensitivity and the easy evaluation of the entire skeleton.³ However, there were often false-positive cases in $^{99\text{m}}\text{Tc}$

bone scintigraphy, because degenerative or inflammatory foci were often confused with metastatic lesions. The addition of single photon emission CT (SPECT) to planar acquisition of $^{99\text{m}}\text{Tc}$ bone scintigraphy has been shown to exhibit a beneficial effect on the detection and evaluation of bone metastases.^{4–6} Skeletal imaging by ^{18}F -fludeoxyglucose positron emission tomography (^{18}F -FDG PET)/CT has been shown to be useful in the detection of bone metastases of various carcinomas including DTC.⁷

Previously, we compared the efficacies of ^{18}F -FDG PET and planar $^{99\text{m}}\text{Tc}$ bone scintigraphy for the detection of bone metastases in patients with DTC.⁸ We found that the specificity and the overall accuracy of ^{18}F -FDG PET for the detection of bone metastases in patients with DTC were

higher than those of planar ^{99m}Tc bone scintigraphy, whereas the difference in the sensitivity of both examinations was not statistically significant, and concluded that ^{18}F -FDG PET is superior to planar ^{99m}Tc bone scintigraphy because of its lower incidence of false-positive results in the detection of bone metastases of DTC.⁸

^{18}F -fluoride is a positron-emitting bone-seeking radiotracer, which has a similar uptake mechanism to ^{99m}Tc -MDP and ^{99m}Tc -HMDP. As the availability of PET systems was increasing, ^{18}F -fluoride has been used for skeletal PET imaging since 1990s. PET or PET/CT with ^{18}F -fluoride have been shown to be more sensitive than planar ^{99m}Tc bone scintigraphy for the detection of bone metastases of lung,⁹ breast,^{10,11} hepatocellular,¹² prostate,^{11,13,14} colon and bladder¹¹ cancers. However, to the best of our knowledge, there have been no systematic comparative studies on the efficacies of ^{18}F -fluoride PET/CT, ^{18}F -FDG PET/CT and ^{99m}Tc bone scintigraphy (planar and SPECT) for the detection of bone metastases of DTC. This study was conducted to compare ^{18}F -fluoride PET/CT, ^{18}F -FDG PET/CT and ^{99m}Tc bone scintigraphy (planar and SPECT) in the detection of bone metastases of DTC.

METHODS AND MATERIALS

Patients

11 patients (8 females, 3 males; age range, 47–75 years; mean age $\pm$ standard deviation, 61.9 ± 8.7 years) with DTC, who had been suspected of having bone metastases after having undergone total thyroidectomy and were hospitalized to be given ^{131}I therapy for ablation of remnants, were selected for this study and evaluated retrospectively. All patients underwent whole-body ^{18}F -fluoride PET/CT and ^{18}F -FDG PET/CT. Both planar and SPECT bone scintigraphies were performed in all patients except one. In addition, planar bone scintigraphy was not performed in another patient. Examinations by all these modalities were performed within 5 weeks before ^{131}I therapy, and ^{131}I scintigraphy was performed after ^{131}I therapy. All procedures followed the clinical guidelines of Nagoya University Hospital and were approved by the institutional review board. Written consent was obtained after a complete description of the study was given to all patients.

^{131}I therapy and ^{131}I scintigraphy

All patients were prepared for ^{131}I therapy by withdrawal of levothyroxine (T4) for 4 weeks and replacement with triiodothyronine (T3) for the first 2 weeks of this period. Patients were instructed to follow a low-iodine diet for 2 weeks prior to ^{131}I therapy. A dose of 3.7–7.4 GBq ^{131}I was administered to patients. Post-therapy whole-body ^{131}I scintigraphy from skull to mid-thigh was obtained 3–4 days after therapy with high-resolution collimation on a dual-head gamma camera (E.CAM®; Toshiba Medical Systems, Tokyo, Japan, or Symbia® S; Siemens Healthcare, Erlangen, Germany).

Planar and single photon emission CT bone scintigraphies

^{99m}Tc bone scintigraphy was performed 3 h after intravenous injection of 740 MBq ^{99m}Tc -HMDP (Nihon Medi-Physics Co., Ltd, Tokyo, Japan) or 740 MBq ^{99m}Tc -MDP (Fujifilm RI Pharma Co., Ltd, Tokyo, Japan). Anterior and posterior whole-body planar images and SPECT images were obtained using a dual-head gamma camera.

^{18}F -fluorodeoxyglucose positron emission tomography/CT

The patients fasted for at least 6 h before ^{18}F -FDG PET/CT. The scan was performed using a modern hybrid scanner (Biograph® 16; Siemens Healthcare). Helical CT slices and PET emission data were acquired from the skull to the mid-thigh in all patients. Image acquisition started 50 min after intravenous injection of 3.7 MBq kg^{-1} ^{18}F -FDG. The emission data acquisition time per bed was 1.5 min. Multidetector CT (MDCT) was acquired using the following parameters: 120 kV, auto-mA, slice thickness of 5 mm and increment of 4 mm.

^{18}F -fluoride positron emission tomography/CT

The scan was performed with the same scanner as for ^{18}F -FDG PET/CT. Helical CT slices and PET emission data were acquired from the skull to the toe in all patients 50 min after intravenous injection of 2.1 MBq kg^{-1} ^{18}F -fluoride. The emission data acquisition time per bed was 2 min. MDCT was acquired using the same conditions as ^{18}F -FDG PET/CT.

Image analysis

The presence of bone metastases was assessed in 16 bone segments: skull; cervical, thoracic and lumbar spines; sacrum with coccyx; sternum; right and left scapulae with clavicles; right and left ribs; right and left pelvises; right and left upper limbs; and right and left lower limbs. The analysis of the images of bone lesions was performed based on the criteria described by Krasnow *et al.*¹⁵ Abnormal uptake located in joints, increased uptake on the edge of vertebral bodies adjacent to the disc space and typical linear uptake were interpreted as arthritis, osteophytes or benign compression fracture. The presence of bone metastases was verified as described previously.⁸ First, the positive finding for bone metastases must be obtained in both ^{131}I scintigraphy and CT. Second, if MRI was performed (in the present study, 4 of the 11 study patients underwent MRI), the MRI finding must indicate the positive metastases. When the positive finding for bone metastases was detected in only one modality other than MRI, *i.e.* either ^{131}I scintigraphy or CT, the bone segment showing such a finding was excluded, because it was unclear whether such a lesion was bone metastases. When a positive finding of bone metastases was detected in none of the three modalities (^{131}I scintigraphy, CT and MRI), the cases were diagnosed as having no bone metastases. All metastatic lesions in the bones were classified into the osteoblastic, osteolytic and mixed-type lesions on the basis of the images on CT scan.

Statistical analysis

The lesion-based sensitivities, specificities and overall accuracies of ^{18}F -fluoride PET/CT, ^{18}F -FDG PET/CT and planar and SPECT ^{99m}Tc bone scintigraphies were analysed by the McNemar test. A value of $p < 0.05$ was considered significant.

RESULTS

9 (82%) of the 11 study patients were finally diagnosed as having bone metastases, and 24 (14%) of all the 176 bone segments were confirmed to have at least 1 bone metastasis. The profiles of the patients and the distribution of metastases in the examined bone segments are shown in Table 1. The higher incidence of bone metastases was observed in the thoracic spine and left

Table 1. Patient profiles and bone metastases

Patient no.	Age (years)	Sex	Type of carcinoma	Cancer staging ^a	Bone metastases															
					Skull	Spine			Sacrum and coccyx	Sternum	Scapulae and clavicles		Ribs		Pelvis		Upper limbs		Lower limbs	
						Cervical	Thoracic	Lumbar			R	L	R	L	R	L	R	L	R	L
1	54	F	Papillary	IVc (T2N1M1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	75	M	Papillary	IVc (T4N1bM1)	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
3	47	M	Follicular	II (T4N1bM1) ^b	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	62	F	Follicular	IVc (T8NxM1) ^c	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
5	65	F	Follicular	IVc (T8NxM1) ^c	-	-	+	-	-	-	-	+	-	-	-	+	-	-	-	+
6	64	F	Papillary	IVc (T1NxM1)	-	+	+	+	+	+	-	-	+	-	+	+	-	-	-	-
7	50	M	Papillary	IVc (T8N1bM1)	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-
8	70	F	Follicular	IVc (T8NxM1) ^c	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-
9	68	F	Follicular	IVc (T8NxM1) ^c	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-
10	59	F	Follicular	IVc (T8NxM1) ^c	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
11	67	F	Follicular	IVc (T2N0M1)	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-

F, female; L, left; M, male; R, right.

^aCancer staging according to the American Joint Committee on Cancer Staging Manual (7th edition) at the time just before total thyroidectomy.^bUnder 45 years at the time of total thyroidectomy.^cDetails of staging of the thyroid gland and lymph nodes were unclear (TxNx) because these patients had undergone total thyroidectomy in hospitals other than ours.

Table 2. Sensitivity, specificity and overall accuracy of ^{18}F -fluoride positron emission tomography (^{18}F -fluoride PET)/CT, ^{18}F -fludeoxyglucose PET (^{18}F -FDG PET)/CT and $^{99\text{mTc}}$ bone scintigraphy [planar and single photon emission CT (SPECT)] in detection of bone metastases in patients with differentiated thyroid carcinoma (patient based)

Parameter	^{18}F -fluoride PET/CT	^{18}F -FDG PET/CT	$^{99\text{mTc}}$ bone scintigraphy (planar)	$^{99\text{mTc}}$ bone scintigraphy (SPECT)
Sensitivity (%)	9/9 (100.0%)	8/9 (88.9%)	6/8 (75.0%)	9/9 (100.0%)
Specificity (%)	2/2 (100.0%)	2/2 (100.0%)	2/2 (100.0%)	2/2 (100.0%)
Accuracy (%)	11/11 (100.0%)	10/11 (90.9%)	8/10 (80.0%)	11/11 (100.0%)

pelvis. 6 (86%) of 7 patients with follicular carcinoma had bone metastases, and 3 (75%) of 4 patients with papillary carcinoma had bone metastases. On a segment basis in bone metastases-positive patients, 13 (14%) of 96 bone segments in patients with follicular carcinoma and 11 (24%) of 48 bone segments in patients with papillary carcinoma had bone metastases, respectively. The differences between these values for follicular and papillary carcinomas on either a patient basis or a segment basis were statistically not significant.

The results on a patient basis of the efficacies of the four imaging modalities in diagnosing the bone metastases of DTC are shown in Table 2. There were no significant differences among the sensitivities of all the four modalities in diagnosing the bone metastases of DTC on a patient basis, although the sensitivity (detection rate) of $^{99\text{mTc}}$ bone scintigraphy (planar) seemed to be lower than that of ^{18}F -fluoride PET/CT, ^{18}F -FDG PET/CT and $^{99\text{mTc}}$ bone scintigraphy (SPECT).

Analytical data on a segment basis concerning the sensitivity, specificity and overall accuracy of the four modalities in diagnosing the bone metastases of DTC are shown in Table 3. The sensitivities of ^{18}F -fluoride PET/CT and $^{99\text{mTc}}$ bone scintigraphy (SPECT) on a segment basis were significantly higher than those of ^{18}F -FDG PET/CT and $^{99\text{mTc}}$ bone scintigraphy (planar) ($p < 0.05$). There were no significant differences among the specificities of these four modalities. The accuracies of ^{18}F -fluoride PET/CT and $^{99\text{mTc}}$ bone scintigraphy (SPECT) on a segment basis were significantly higher than that of $^{99\text{mTc}}$ bone scintigraphy (planar) ($p < 0.05$).

Among 24 metastatic bone lesions, 12 (50%) were classified as osteolytic and 9 (38%) as osteoblastic lesions on the basis of the CT images, but 3 (13%) could not be classified because of their unclear CT images. The sensitivities of the four modalities in detecting the osteolytic and osteoblastic lesions are shown in Table 4. The sensitivities of ^{18}F -FDG PET/CT and $^{99\text{mTc}}$ bone scintigraphy (planar) for the osteoblastic lesions were lower than those of ^{18}F -fluoride PET/CT and $^{99\text{mTc}}$ bone scintigraphy (SPECT). However, the differences in the sensitivities between the former two and the latter two modalities were not statistically significant because of the small number of total examined cases. The sensitivities of all the four modalities for the osteolytic lesions were high.

Location, type and size of the 24 metastatic bone lesions and uptake of tracers in the lesions observed by the 4 modalities are shown in Table 5. All 24 bone metastatic lesions exhibited positive uptake in ^{131}I scintigraphy. As shown in Table 3 and described above, ^{18}F -FDG PET/CT and $^{99\text{mTc}}$ bone scintigraphy (planar) were significantly less sensitive than ^{18}F -fluoride PET/CT in diagnosing the bone metastases of DTC. As shown in Table 5, 6 of a total of 24 metastatic bone lesions exhibited negative results in both ^{18}F -FDG PET/CT and $^{99\text{mTc}}$ -bone scintigraphy (planar) but were positive in ^{18}F -fluoride PET/CT. Four of these six lesions were osteoblastic and small sized (long diameter < 2.5 cm), and in the other two lesions the type was unclear and the lesion size was indeterminable. 17 of 24 metastatic bone lesions were uptake positive in both ^{18}F -fluoride PET/CT and ^{18}F -FDG PET/CT; the mean of the long diameters of the 17 lesions was 3.75 ± 1.42 cm, and 12 of the 17 lesions were osteolytic, 4

Table 3. Sensitivity, specificity and overall accuracy of ^{18}F -fluoride positron emission tomography (^{18}F -fluoride PET)/CT, ^{18}F -fludeoxyglucose PET (^{18}F -FDG PET)/CT and $^{99\text{mTc}}$ bone scintigraphy [planar and single photon emission CT (SPECT)] in detection of bone metastases in patients with differentiated thyroid carcinoma (lesion based)

Parameter	^{18}F -fluoride PET/CT	^{18}F -FDG PET/CT	$^{99\text{mTc}}$ bone scintigraphy (planar)	Scintigraphy (SPECT)
Sensitivity (%)	23/24 (95.8%)	17/24 (70.8%) ^a	14/22 (63.6%) ^a	21/24 (87.5%)
Specificity (%)	151/152 (99.3%)	152/152 (100.0%)	136/138 (98.6%)	150/152 (98.7%)
Accuracy (%)	174/176 (98.9%)	169/176 (96.0%)	150/160 (93.8%) ^b	171/176 (97.2%)

^aThe sensitivities of ^{18}F -fluoride PET/CT and $^{99\text{mTc}}$ bone scintigraphy (SPECT) were significantly higher than those of ^{18}F -FDG PET/CT and $^{99\text{mTc}}$ bone scintigraphy (planar) ($p < 0.05$).

^bThe accuracies of ^{18}F -fluoride PET/CT and $^{99\text{mTc}}$ bone scintigraphy (SPECT) were significantly higher than that of $^{99\text{mTc}}$ bone scintigraphy (planar) ($p < 0.05$).

Table 4. Sensitivity of ^{18}F -fluoride positron emission tomography (^{18}F -fluoride PET)/CT, ^{18}F -fluorodeoxyglucose PET (^{18}F -FDG PET)/CT and $^{99\text{m}}\text{Tc}$ bone scintigraphy [planar and single photon emission CT (SPECT)] for osteoblastic and osteolytic metastases in patients with differentiated thyroid carcinoma

Type of lesion	^{18}F -fluoride PET/CT	^{18}F -FDG PET/CT	$^{99\text{m}}\text{Tc}$ bone scintigraphy (planar)	$^{99\text{m}}\text{Tc}$ bone scintigraphy (SPECT)
Osteoblastic	8/9 (89%)	4/9 (44%)	5/9 (56%)	9/9 (100%)
Osteolytic	12/12 (100%)	12/12 (100%)	9/10 (90%)	12/12 (100%)
Unclear	3/3 (100%)	1/3 (33%)	0/3 (0%)	0/3 (0%)

osteoblastic, and 1 unclear. The difference in the long diameters between the metastatic bone lesions that were uptake positive in both ^{18}F -fluoride PET/CT and ^{18}F -FDG PET/CT and those that were positive in ^{18}F -fluoride PET/CT but negative in ^{18}F -FDG PET/CT (1.8 ± 0.41 cm) was statistically significant ($p < 0.05$).

Example images of bone metastases of DTC by ^{18}F -fluoride PET/CT, ^{18}F -FDG PET/CT, $^{99\text{m}}\text{Tc}$ bone scintigraphy (planar) and $^{99\text{m}}\text{Tc}$ bone scintigraphy (SPECT) are shown in Figure 1.

DISCUSSION

The unusually high incidence of bone metastases in the patient group with DTC examined in this study was owing to the fact that patients with DTC, who had been suspected of having bone metastases after having undergone total thyroidectomy and were referred for the purpose of ^{131}I therapy to our clinic in the university hospital, were selected for study. Follicular carcinoma in DTC reportedly has a higher incidence of bone metastases than papillary carcinoma. Our previous study also showed the same result, *i.e.* 13 (87%) of 15 patients with follicular carcinoma and only 3 (10%) of 29 patients with papillary carcinoma had bone metastases.⁸ In the present study, 6 (86%) of 7 patients with follicular carcinoma and 3 (75%) of 4 patients with papillary carcinoma had bone metastases (Table 1). The difference between these values was not significant because of the small number of study patients.

The specificity of planar $^{99\text{m}}\text{Tc}$ bone scintigraphy in the detection of bone metastases in DTC obtained in this study (98.6%) was higher than that obtained in the previous study (91.4%)⁸ because of fewer false-positive cases in this study (2/138 on a segment basis; 1.4%) than in the previous study (39/451; 8.6%). Since the previous study, we have found that abnormal uptake findings mainly observed at the joint and edges of vertebral bodies except true bone metastases of DTC could be occasionally false positive and therefore should be excluded from the bone metastases. As stated in the Methods and materials, such uptake findings in planar $^{99\text{m}}\text{Tc}$ scintigraphy were not counted as positive in the present study.

In the present study, ^{18}F -fluoride PET/CT showed significantly higher sensitivity than $^{99\text{m}}\text{Tc}$ bone scintigraphy (planar) in detecting bone metastases of DTC (Table 3); the results agree with those of the earlier studies on ^{18}F -fluoride PET or PET/CT with bone metastases of lung,⁹ breast,^{10,11} hepatocellular,¹² prostate,^{11,13,14} colon and bladder¹¹ cancers. In the present study, however, the specificities of both ^{18}F -fluoride PET/CT and $^{99\text{m}}\text{Tc}$ bone scintigraphy (SPECT) in detecting bone metastases

of DTC were similarly high and did not differ significantly from one another (Table 3), indicating that the sensitivity of $^{99\text{m}}\text{Tc}$ bone scintigraphy (planar) was improved when SPECT was added to a planar scan. This finding is consistent with those of the earlier studies with bone metastases of various cancers.⁶ It was also reported that detection of bone metastases of breast cancer was improved by SPECT compared with planar bone scintigraphy, although it was further improved by ^{18}F -fluoride PET/CT compared with SPECT.¹³

The sensitivity of ^{18}F -FDG PET/CT on a segment basis obtained in the present study (17/24, 70.8%) was lower than that of ^{18}F -FDG PET obtained in our previous study (50/59, 84.7%).⁸ In general, bone metastases of cancer are classified into the osteoblastic, osteolytic, mixed and invisible types based on the CT images. A total of 24 bone metastases of DTC in the patient population examined in the present study were classified into 9 (38%) osteoblastic and 12 (50%) osteolytic types, and the remaining 3 could not be classified. This distribution of the types of bone metastases of DTC examined in the present study was different from that in the previous study; namely, osteoblastic 7 (11%)/62, osteolytic 52 (84%)/62 and mixed 3 (5%)/62.⁸ The lower sensitivity of ^{18}F -FDG PET/CT in the present study was considered owing to the fact that the metastatic bone lesions examined in the present study included more osteoblastic type of lesions than the previous study. 6 of a total of 24 metastatic bone lesions examined in the present study exhibited negative results in both ^{18}F -FDG PET/CT and $^{99\text{m}}\text{Tc}$ bone scintigraphy (planar) but were positive in ^{18}F -fluoride PET/CT. Four of the six lesions, except two lesions, the type of which was unclear and the size of which was indeterminate, were osteoblastic and small sized (long diameter < 2.5 cm).

It was reported that ^{18}F -FDG PET/CT was superior to bone scintigraphy in the detection of osteolytic bone metastases from non-small-cell lung cancer and may obviate the need to perform additional bone scans or ^{18}F -fluoride PET in the staging of non-small-cell lung cancer.¹⁶ A study into bone metastases from breast cancer showed that ^{18}F -FDG PET had limitations in depicting metastases of the osteoblastic type, although it was useful for detection of bone metastases from breast cancer.¹⁷ Another study into bone metastases from breast cancer showed that ^{18}F -FDG PET was inferior to $^{99\text{m}}\text{Tc}$ bone scintigraphy in the detection of osteoblastic lesions (74% vs 95%) but was superior in the detection of osteolytic lesions (92% vs 73%).¹⁸ The lower sensitivity of ^{18}F -FDG PET in the detection of osteoblastic lesions from breast cancer was similar to that observed with bone metastases from DTC in the present study. However, the sensitivity

Table 5. Location, type, and size of metastatic bone lesions and uptake in positron emission tomography (PET)/CT and scintigraphies

Patient no.	Bone segments with metastases	Type of lesion	Size of lesion (long diameter × short diameter, cm)	Uptake				
				¹⁸ F-fluoride PET/CT	¹⁸ F-FDG PET/CT	^{99m} Tc scintigraphy (planar)	^{99m} Tc scintigraphy (SPECT)	¹³¹ I scintigraphy
2	L rib	Osteoblastic	1.7 × 1.4	+	–	–	+	+
4	Sternum	Osteolytic	1.4 × 1.3	+	+	–	+	+
	Thoracic spine	Osteolytic	4.4 × 2.0	+	+	+	+	+
	R scapula and clavicle	Osteoblastic	2.5 × 1.8	+	–	–	+	+
	L scapula and clavicle	Unclear	Indeterminable	+	–	–	–	+
5	L pelvis	Osteoblastic	2.7 × 1.9	+	+	+	+	+
	L lower limb	Unclear	Indeterminable	+	–	–	–	+
	Cervical spine	Osteoblastic	1.6 × 1.5	+	–	+	+	+
	Thoracic spine	Osteoblastic	4.5 × 2.5	+	+	+	+	+
	Lumbar spine	Osteoblastic	2.6 × 2.3	+	+	+	+	+
	Sacrum and coccyx	Osteoblastic	3.1 × 3.0	+	+	+	+	+
6	Sternum	Osteolytic	4.7 × 2.8	+	+	+	+	+
	R rib	Osteoblastic	1.5 × 0.6	+	–	–	+	+
	R pelvis	Osteolytic	4.5 × 2.6	+	+	+	+	+
	L pelvis	Osteoblastic	4.8 × 2.7	+	+	+	+	+
	Thoracic spine	Unclear	Indeterminable	+	+	–	–	+
7	L rib	Osteolytic	3.9 × 3.2	+	+	+	+	+
8	Thoracic spine	Osteolytic	3.2 × 2.5	+	+	+	+	+
	L pelvis	Osteolytic	3.8 × 3.3	+	+	+	+	+
	Sacrum and coccyx	Osteolytic	7.1 × 3.8	+	+	+	+	+
9	Thoracic spine	Osteoblastic	1.5 × 1.1	+	–	–	+	+
10	L pelvis	Osteolytic	4 × 3.3	+	+	+	+	+
11	R pelvis	Osteolytic	6.3 × 4.3	+	+	^a	+	+
	Skull	Osteolytic	1.6 × 1.5	+	+	^a	+	+

¹⁸F-FDG PET, ¹⁸F-fluorodeoxyglucose PET; ¹⁸F-fluoride PET, ¹⁸F-fluoride positron emission tomography; L, left; R, right; SPECT, single photon emission CT. Patients 1 and 3 who had no bone metastases are not included in this table.

^aPatient 11 did not undergo planar ^{99m}Tc scintigraphy.

Figure 1. Multiple bone metastases in Patient 5. (a) From left to right: ^{131}I scintigraphy, ^{18}F -fluoride positron emission tomography (^{18}F -fluoride PET)/CT, ^{18}F -fluorodeoxyglucose PET (^{18}F -FDG PET)/CT, and anterior and posterior planar bone scintigraphies. Bone metastases at left pelvis and thoracic spine could be detected by all four modalities. (b, c) From left to right (metastases are marked by arrows): ^{18}F -fluoride PET/CT, ^{18}F -FDG PET/CT and single photon emission CT (SPECT) bone scintigraphy. (b) Bone metastasis at right clavicle could be detected by ^{18}F -fluoride PET/CT and SPECT bone scintigraphy, but not by ^{18}F -FDG PET/CT. (c) Bone metastasis at left scapula could be detected by ^{18}F -fluoride PET/CT, but not by ^{18}F -FDG PET/CT and SPECT bone scintigraphy.

of $^{99\text{m}}\text{Tc}$ bone scintigraphy (planar) in the detection of osteoblastic lesions from DTC was as low as that of ^{18}F -FDG PET/CT.

The patients examined in this study had an unusually high incidence of bone metastases. Six of nine patients with bone metastases had bifocal or multiple metastatic bone lesions, whereas the other three of nine patients had solitary lesions. In the present stage of our studies, it is unknown yet whether the peculiarity of the study patients can influence comparison of the efficacy of each modality in the detection of bone metastases of DTC. In addition, the number of patients in this study seemed to be too small to make reliable comparison of the utility of each modality in the detection of bone metastases of DTC. Further

studies with increased numbers of study patients with ordinary bone metastases will be needed for elucidation of these problems.

In conclusion, this pilot study suggests that the sensitivity and accuracy of ^{18}F -fluoride PET/CT for the detection of bone metastases of DTC are significantly higher than those of $^{99\text{m}}\text{Tc}$ bone scintigraphy (planar). The sensitivity and accuracy of $^{99\text{m}}\text{Tc}$ bone scintigraphy (SPECT) are improved near to those of ^{18}F -fluoride PET/CT. The sensitivity of ^{18}F -FDG PET/CT for the detection of bone metastases of DTC is significantly lower than that of ^{18}F -fluoride PET/CT or $^{99\text{m}}\text{Tc}$ bone scintigraphy (SPECT).

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