CASE REPORT

^{31}P MR Spectrum of Non-Hodgkin's Lymphoma of Bone in Comparison with Those of Osteosarcoma

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Image-localized ^{31}P magnetic resonance spectroscopy was performed in a patient with non-Hodgkin's lymphoma (NHL) of bone, and 7 patients with osteosarcoma. Analyzed were five spectra, one NHL of bone and 4 osteosarcomas, which satisfied the following criteria ; signal-to-noise ratio is greater than 2.0, and phosphomonoester (PME) peak is well resolved from Pi peak. Both PME/NTP and PME/phosphodiester were higher in bone NHL than osteosarcomas. Signal intensity were summed for all resonance peaks in a spectrum and compared among 4 bone tumors in similar anatomical location. An NHL of bone showed a higher overall signal intensity than 3 osteosarcomas. In contrast to osteosarcomas, an NHL of bone had a phosphorous spectrum characterized as having a higher PME peak as well as intensive overall metabolite signal.

INTRODUCTION

MR spectroscopic studies of bone and soft tissue lesions demonstrated that an intensity of phosphomonoester (PME) resonance relative to NTP, γ-NTP or β-NTP in malignant diseases was different from those in benign ones[1),2)], and PME/NTP was found to be high in high-grade lesions[3)]. High PME/NTP is frequently observed in many malignant diseases, but not specific to them. Moreover, it seems to be agreed that there is not obvious correlation of phosphorus MR spectra with any specific tumor type of extremities[3),4)]. Signal contamination from surrounding tissues might obscure the true spectra of the lesion being studied. Spectra of extremity lesion measured without three-dimensional localization would contain a non-negligible amount of signal from the surrounding muscle as contamination. Amount of contamination relative to the net signal of the le-

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sion will depend on the size of coil used and also on the volume of the lesion of interest. Therefore, localization technique should be taken into account in evaluating MR spectra. Low PME content in the muscle would fortunately make PME resonance a somewhat sensitive indicator of abnormalities.

We observed a trend toward a higher crude signal intensity on a phosphorus spectrum per unit volume of a voxel in malignant extremity lesions than in benign ones[2], suggesting a higher metabolic activity and/or cellularity in malignant lesions.

In our MR spectroscopic study of extremity tumors, it was found and was shown here that non-Hodgkin's lymphoma of bone had a specific spectral pattern which was different from those of osteosarcomas.

SUBJECTS AND METHODS

Subjects of this study were 8 patients with bone tumors ; one non-Hodgkin's lymphoma (NHL, diffuse medium B cell type, stage IV), and 7 osteosarcomas. All were previously untreated. They all gave informed consent to the MR studies.

MR spectroscopy was performed on a 1.5 T MRI/S system (Gyroscan S15, Philips, The Netherlands) using a 14-cm surface coil of transmitter-and-receiver type with an adiabatic pulse. Size and location of a voxel for signal localization was determined on T_1-weighted images, and/or T_2-weighted ones. Shimming of the magnetic field was done automatically for this voxel, and the homogeneity was generally achieved up to 15 Hz measured as a FWHM (full-width at half-maximum) of signal of tissue water within the voxel.

Measurement techniques of phosphorus spectroscopy were as follows ; TR of 2 sec, spectral span width of 3000 Hz, sampling of 1024 points, and localization by ISIS[5]. Detected free induction decay (FID) was processed by convolution difference of 200 Hz (factor 0.5) and exponential line broadening filter of 8 Hz. Manual phase correction and base line flattening was done on a Fourier transformed spectrum. Signal intensity was calculated by Lorentzian curve fitting, and parameters were iteratively adjusted so as to minimize the residual error. To evaluate the overall metabolite signal intensity, total signal intensity was calculated as the sum of peak intensity in a spectrum[6], excluding phosphocreatine (PCr) because it is possibly a contamination from surrounding muscles.

In order to increase statistical reliability, spectra with PME and NTP peaks of sufficient signal-to-noise ratios were selected. The criteria were as follows ; first, both PME/noise and NTP/noise were equal to or larger than 2.0, and second, PME was resolved from Pi peak. The latter criterion is to decrease Pi contribution into the evaluation of PME intensity. Noise used here was calculated as $1.96\times$ (root-mean-square of noise). Cases which satisfied these criteria were 1 NHL of bone and 4 osteosarcomas (Table).

RESULTS AND DISCUSSION

MR spectra were shown with MR images in Figures 1 and 2. Figure 1 shows an NHL of the iliac bone (case 1) ; the lesion had a low signal

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Table List of Subjects and Spectral Data

Case	Sex	Age	Histology*	Lesion site	Voxel size (cm)	Peak intensity ratio		TSI**
						PME/γNTP	PME/PDE	
1 TT	M	60	NHL of bone	Iliac bone	6×7×5	1.81	1.73	5.33(2.5)
2 FT	F	81	Osteosarcoma	Iliac bone	5×5×6	0.83	0.70	2.4 (1.6)
3 YS	F	58	Osteosarcoma	Iliac bone	6×7×7	0.88	0.31	2.8 (0.95)
4 MT	F	62	Osteosarcoma	Prox. Femur	6×8×7	0.67	0.39	3.2 (0.95)
5 NI	F	14	Osteosarcoma	Femur	4.5×12×5	0.98	0.43	—

* NHL : Non-Hodgkin's lymphoma

** Total signal intensity measured on a spectrum, and number in parenthesis is TSI per unit volume of voxel ($\times 10^{-2}$)

on T_1-weighted image(A), and inhomogeneous, high intensity on T_2-weighted image(B). It was stained inhomogeneously after Gd-DTPA injection (C). On MR images, this lesion could hardly be specified further. Localized spectrum of the lesion showed prominent PME, and phosphodiester (PDE) was lower than PME and NTP (E).

Figure 2 shows a case with osteosarcoma of the proximal femoral bone (case 4). The lesion had a slightly low signal intensity on proton density image (A), and a spectrum obtained from the voxel within the tumor shows intensive peaks of PME, PDE and NTP, but peak heights of these resonances were comparable to each other (C) on contrary to NHL of bone (Fig. 1(E)).

For an NHL of bone, PME/γ-NTP and PME/PDE were calculated as 1.81 and 1.73, respectively, by Lorentzian curve fitting (Fig. 1(F)), both of which were higher than those of osteosarcomas (Table).

In the study of 13 osteosarcomas, PME/PDE was averaged to be 0.65 including 1 case with the ratio higher than 1.0, and mean PME/γ-NTP was 0.56 including 1 case with the ratio greater than 1.0[4]. Our data for osteosarcomas were consistent with these averaged data as shown in Table. On the spectrum of a osteosarcoma shown by Ross et al.[7], peak heights of PME and PDE seem to be similar to each other.

Spectroscopic data of NHL of bone were few in literature ; one spectrum showed a higher PME than PDE in an NHL of B-cell type[7], but Negendank et al.[1] measured spectrum using TR of 1 sec and showed a spectrum of an NHL, a diffuse cell type, with PME/β-NTP of 0.91 and PDE/NTP of 2.21.

A large series of NHLs published recently[8] demonstrated large PME signals in ^{1}H-decoupled ^{31}P spectra. Spectra from all of the patients had a prominent PME peak and small PDE, which is similar to the spectrum of bone NHL in this study measured without ^{1}H-decoupling (Fig. 1(E)). NHLs are relatively uniform in their metabolic characteristics, and there exist no significant trends in metabolite ratios among different grade NHLs[8]. Metabolite signal intensities expressed as fractions of total phosphorus signal were averaged as 26% for PME, 20% for PDE, and 47% for NTP in 18 NHLs in tissues other than spleen[8]. Assuming γ-NTP signal to be one thirds of total NTP, PME/γ-NTP and PME/PDE could be calculated to be 1.65 and 1.3, respectively. Both PME/

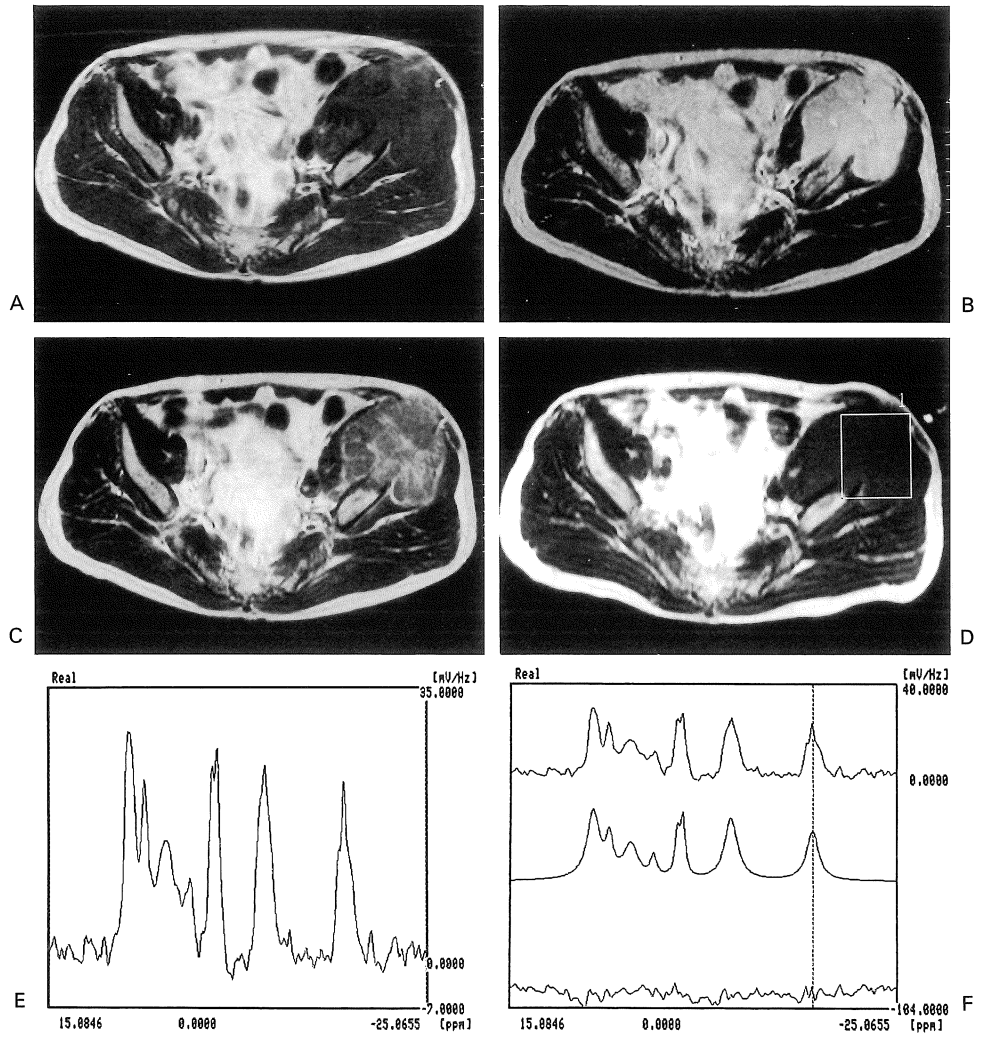

Fig. 1. A 60-y.o. male with non-Hodgkin's lymphoma of the iliac bone. (A) T_1-weighted image, (B) T_2-weighted image, (C) Gd-enhanced T_1-weighted image, (D) Voxel ($6 \times 7 \times 5$-cm) for MRS on a scout image, (E) ISIS-localized spectrum of the lesion, and (F) original spectrum (upper) and fitted spectrum using Lorentzian curves (middle).

γ-NTP and PME/PDE of a bone NHL measured in this study (Table) were consistent with those data.

Total signal intensity in a spectrum was found to correlate to necrotic ratio of a pathological specimen, and to be potentially an indicator of the effectiveness of tumor therapy[6]. And, spectroscopic study of extremity lesions showed that total signal intensity per unit volume of voxel was higher in malignant tumors than in benign lesions[2].

Total signal intensity in a spectrum per unit volume of a voxel was calculated in 4 cases with bone tumors in the pelvic region (Table).

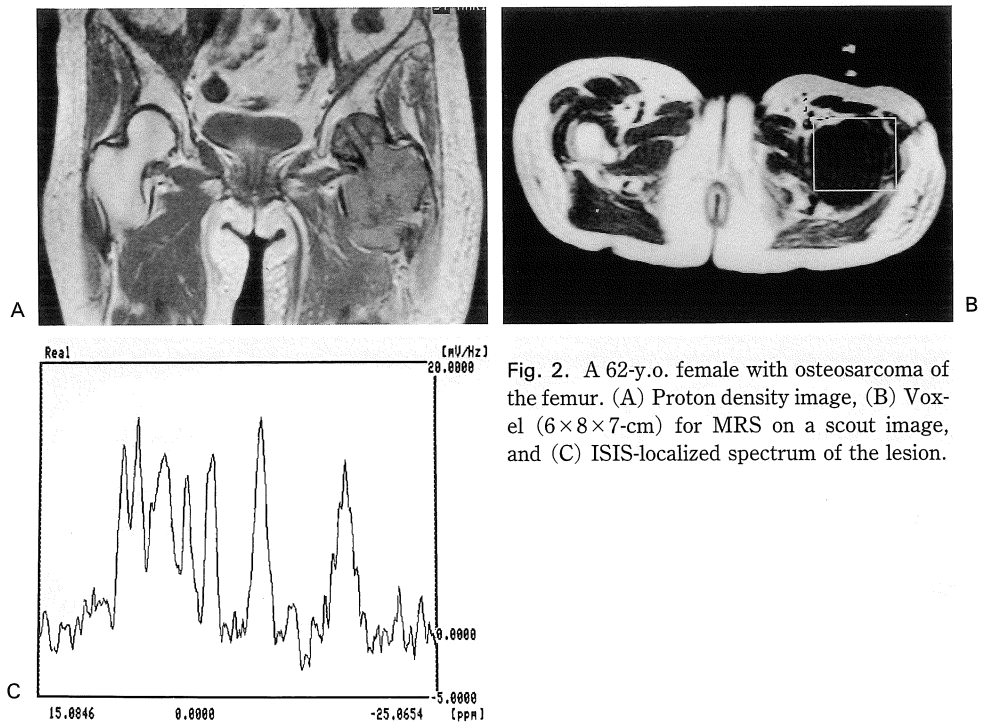

Fig. 2. A 62-y.o. female with osteosarcoma of the femur. (A) Proton density image, (B) Voxel (6×8×7-cm) for MRS on a scout image, and (C) ISIS-localized spectrum of the lesion.

It was higher in an NHL of the iliac bone than three osteosarcomas ; two of the iliac bone (cases 2 and 3) and one of the proximal femoral bone (case 4) (Table). As the anatomical location of these four cases were similar, total signal intensity per unit volume of voxel calculated without any sensitivity corrections would give some estimation of metabolite content in a voxel. High signal intensity in an NHL of bone presumably reflects higher overall cellularity than osteosarcomas.

Phosphoethanolamine(PE) was determined as the major component of PME in a lymphatic lymph node by Dixon et al.[9], and Negendank et al. showed via ^{1}H-decopled ^{31}P spectroscopy that PE is the major component of NHLs[8]. Chemical shift of PME peak measured from Pi peak was 1.70 ppm in the well-resolved *in vivo* spectrum of bone NHL (Fig. 1(E)). It strongly suggests PE, instead of phosphocholine, as a major component of PME[10].

In conclusion it was shown that a pshophorus MR spectrum of a non-Hodgkin's lymphoma of bone had an intensive PME peak and high overall phosphorous signal in contrast with osteosarcomas.

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Abbreviations :
FID (free induction decay)
FWHM (full-width at half-maximum)
NHL (non-Hodgkin's lymphoma)
PCr (phosphocreatine)
PDE (phosphodiester)
PE (phosphoethanolamine)
PME (phosphomonoester)