TECHNICAL NOTE

Phosphorous-31 Magnetic Resonance Spectroscopy of Cervical Cancer Using Transvaginal Surface Coil

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We developed a new transvaginal coil tuned for phosphorous-31 and measured its magnetic resonance spectroscopy (³¹P MRS) of uterine cervical cancer. In a 50-year-old woman with uterine cervical cancer (International Federation of Gynecology and Obstetrics [FIGO] stage IIb), ³¹P MRS with the new coil clearly differentiated the low intensity of phosphocreatinine (PCr) and high intensity of phosphomonoester (PME) in tumor from those in muscle. Results suggests that this method will be useful for assessing uterine cervical cancer.

Keywords: *phosphorous-31 magnetic resonance spectroscopy (³¹P MRS), uterine cervical cancer, transvaginal coil, phosphomonoester, phosphocreatinine*

Introduction

Radiation therapy has been recognized as one of the most effective treatment modalities for cancer of the uterine cervix. If the radiosensitivity or probability of local control of tumor could be adequately assessed during or at the end of radiation therapy and the treatment of patients with expected recurrence could be thereby modified, improved patient survival could well be expected. Although magnetic resonance (MR) imaging is useful for the anatomical localization of intrapelvic tumors, it is sometimes nonspecific for the characterization of tumors, and differential diagnosis of the malignancy of a tumor can be difficult using MR and other clinical imaging.¹ Some studies evaluate intrapelvic tumors by proton magnetic resonance spectroscopy (¹H MRS), but the signal of the presence of choline cannot be used for differential diagnosis between benign and malignant tumors.¹

Phosphorous-31 MRS (³¹P MRS) has significant potential in assessing the radiation response of human tumors because the phosphorous metabolism of energy and membrane phospholipids can be

measured *in vivo*.² Radiation responses of experimental and human tumors have been investigated using ³¹P MRS.^{2–5} However, uterine cervical cancer has not been studied because the depth of the uterine cervix from the surface of the body does not allow acquisition of ³¹P MR signals with the usual surface coil. Therefore, we developed a transvaginal coil that enables the measurement of ³¹P MR signals of uterine cervical cancer, and we succeeded in obtaining unique MR spectra from the cancer.

Materials and Methods

Preliminary examination (³¹P MRS in muscle)

³¹P MRS in normal human quadriceps femoris muscle was performed to evaluate the transvaginal coil (Fig. 1). A 2-turn surface coil (33 × 21 mm) was made for this study. The coil was attached to the surface of the lower leg and set at the edge of an acrylic resin cylinder at an angle of 30°. The respective diameters of the outer and inner surfaces of the cylinder were 29 mm and 24 mm. The surface coil was tuned for phosphorous (25.9 MHz) with 2 variable condensers (25 pF; Voltronics Corporation, USA) and one fixed condenser (20 pF; Dielectric Laboratories Corporation, USA) in the cylinder. Tuning and matching before MR spectroscopy scan were adjusted by changing the capacities of the

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Fig. 1. Transvaginal phosphorous-31 magnetic resonance (^{31}P MR) spectroscopy coil consisting of a 2-turned surface coil tuned for ^{31}P resonance, 2 variable capacitors (VC) for tuning and matching the coil, 2 flexible bars, and a cylinder that contains them. The surface coil is inclined at 30° . A screwdriver is inserted into guide tubes to adjust the tuning and matching.

variable condensers with 2 flexible bars made of acrylic resin. A coaxial cable (5D-2V; Fujikura, Japan) was used. MR examinations were performed with a 1.5T imager equipped with a superconductive and horizontal-bore magnet (Gyrosan ACS2; Philips Medical Systems). The volume of interest (VOI; $10 \times 10 \times 10$ cm) was localized with image-selected *in vivo* spectroscopy (ISIS) sequence to avoid contamination of the ^{31}P MR signals of the uterine cervix by other signals on the opposite side of the coil. Although the VOI was localized widely, the actual volume in which ^{31}P signals could be acquired was limited to less than 8 cm^3 because the sensitive area of the signals is determined by the coil size. A 90° pulse was obtained by frequency-modulated adiabatic excitation. The following parameters were used: pulse repetition time (TR) = 3000 ms, data size = 1024 data points, spectral width = 2000 Hz, number of signal averages = 256. The spectra were processed with a 15-Hz exponential filter in the time domain.

Patient preparation

A 50-year-old woman with uterine cervical cancer (International Federation of Gynecology and Obstetrics [FIGO] stage IIIB, squamous cell carcinoma, keratinizing) was studied. MR imaging showed the tumor extended to the pelvic wall. She was asked to participate in the study and was

Fig. 2. Transvaginal phosphorous-31 magnetic resonance (^{31}P MR) spectroscopy coil inserted into a 50-year-old woman with uterine cervical carcinoma (International Federation of Gynecology and Obstetrics [FIGO] stage IIIB). The surface coil is located just under the tumor. We compared ^{31}P MR spectroscopy using volume-selection (ISIS; dashed-line square) with a nonlocalized ISIS.

Fig. 3. Sagittal magnetic resonance (MR) images of transvaginal phosphorous-31 magnetic resonance (^{31}P MR) spectroscopy coil inserted into a 50-year-old woman with uterine cervical carcinoma (International Federation of Gynecology and Obstetrics [FIGO] stage IIIB).

admitted after informed consent was obtained according to institutional guidelines. After the patient was placed on the bed of the MR system, an experienced gynecologist carefully inserted the transvaginal coil. Locating the surface coil at the position nearest the cancer was accomplished using coronal and sagittal scout images ($\text{TR} = 4500$ ms, echo time $[\text{TE}] = 100$ ms) (Figs. 2, 3). MR spectroscopy was examined using the same parameters as those used in the preliminary study of the quadriceps femoris muscle. Shimming was performed using proton MR spectroscopy within the VOI ($20 \times 20 \times 20$ mm) at the same center and direction as the VOI for the localized ^{31}P MR spectroscopy. We compared the ^{31}P MRS localized with the ISIS and without volume selection. Acceptable field

homogeneity was reached using a maximum line width of 15 Hz. After tuning and matching of the transvaginal coil, the measurement of ^{31}P MR spectroscopy was started.

Results

Preliminary examination (^{31}P MRS in muscle)

The ^{31}P MRS of normal human muscle with the transvaginal coil is shown in Fig. 4. The signal-to-noise ratio of phosphocreatine (PCr) was 27.6, and the ^{31}P MR signal pattern was equal to that of muscles previously reported.⁶

Transvaginal ^{31}P coil and MR measurements

Two lines of ^{31}P MR spectra were obtained using the transvaginal coil. One was localized with the

Fig. 4. Phosphorous-31 magnetic resonance (^{31}P MR) signals in the muscle. The strongest peak was obtained from phosphocreatine (PCr). Three peaks from nucleoside triphosphate (NTP) and a peak from inorganic phosphate (Pi) were also detected.

ISIS (Fig. 5A), and the other was acquired without volume selection (Fig. 5B). In the localized MRS, PCr was barely detected, and the signal intensity of phosphomonoester (PME) was high. In the nonlocalized MR spectroscopy, a high signal peak of PCr was considered to be contamination by other tissues, such as muscles.

Discussion

The ^{31}P MRS of muscle with the transvaginal coil was thought to be excellent, certainly sufficient for measurement *in vivo*. Because signals from other tissues contaminated ^{31}P MR signals in cervical cancer using a nonlocalizing pulse sequence, use of the coil with localizing techniques, such as ISIS, would be preferable.

Low intensity of PCr and high intensity of PME were characteristic in the ^{31}P MR spectroscopy of cancer.⁴ Inorganic phosphate and phosphocreatine play important roles in oxidative phosphorylation.^{2,6} Increased inorganic phosphate (Pi) and decreased PCr are reported with low energy status, whereas decreased Pi and increased PCr are seen with high energy status. As in tumor tissue, the tricarboxylic acid (TCA) cycle is regarded to work inefficiently, and the low intensity of PCr of the

Fig. 5. Magnetic resonance (MR) signals around the uterine cervix (A) with and (B) without volume selection. A strong peak of phosphocreatine (PCr) was obtained in the phosphorous-31 (^{31}P) MR signals without volume selection, suggesting that these signals were contaminated by other tissues, such as muscle. The ^{31}P MR signal with volume selection showed a high intensity peak of phosphomonoester (PME) and a very small peak of PCr. Three peaks from nucleoside triphosphate (NTP), a peak from phosphodiester (PDE) and a peak from inorganic phosphate (Pi) were also detected.

cervical carcinoma in this study is reasonable. The signals of PMEs are considered to be delivered mainly from some kind of phospholipids, precursors of organic membrane, thought to increase with cellular growth. In fact, many reports suggest that the high peak of PME appears under the condition of high cellular growth, such as that of tumor tissue.²⁻⁴

^{31}P MRS is a noninvasive tool to measure tumor activity and metabolism. Thus, we consider it to be useful for the early evaluation of response to radiation and chemotherapy of uterine cervical cancer, although there will be a limitation, including the contractionary effect, by the therapies.⁷ Additionally, assessment of the radiosensitivity of the target tumor may be possible by comparing ^{31}P MR signals from the tumor prior to radiation with those of an early phase of irradiation.

^{31}P MRS in cervical cancer was successfully obtained *in vivo*, suggesting this method as useful for assessing uterine cervical cancer.

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