In Vivo Quantitative Proton MR Spectroscopy to Characterize Morphological Pattern of MR Enhancements in Breast Cancer

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Introduction

Recent in vivo proton MR spectroscopy (¹H-MRS) studies conducted at clinical MR scanners have shown that in vivo ¹H-MRS can be used to distinguish between malignant and benign tissues based on the detection of total choline-containing compounds (tCho). However, previous breast studies at 1.5T have shown a variable sensitivity (67%- 100%) from study to study [1]. In addition to the intrinsic heterogeneous nature of breast tumors [2], the limitations of in vivo breast ¹H-MRS detection may also contribute to a complicated tCho distribution pattern. For example, tCho detection may be more difficult in diffusive-enhancement-type cancers because of the intermingling of tumor cells with adipose tissues [3]. The tCho level was higher in lesions presenting as mass-type lesions compared to non-mass-type diffuse enhancement. However, further investigation in a large population is needed. In this study, we reported a larger series study to further investigate if the tCho SNR, tCho concentration, and lipids ratio (e.g., CH₃ at 1.3 ppm/CH₂ at 0.9 ppm) levels show difference between mass and non-mass type breast cancers. The aim of our study was to determine whether in vivo ¹H-MRS can provide useful information for characterizing tumor morphology (mass or non-mass) in breast cancer.

Methods

Of ninety-nine cases with breast tumors, forty-four were included in this study. The inclusion criteria were patients with malignant lesions that measured 1.5 cm or larger on MR images and with tCho detection (e.g., tCho peak area to noise ratio > 3 and tCho CRLB < 30%) by ¹H-MRS. The 1.5T MR imaging protocol consisted of high-resolution precontrast imaging from the concerned breast, bilateral dynamic contrast-enhanced imaging, and ¹H-MRS. After the MRI study was completed, single-voxel ¹H-MRS was performed using a point-resolved spin-echo sequence (PRESS). The spectroscopic voxel size was from 3.4 to 8.0 mL (1.5-2 cm cubic voxel). The acquisition parameters were TR/TE=2000/270 ms, and acquisition averages of 128. An unsuppressed spectrum was also acquired to measure water and lipids signals (32 averages). We quantified tCho peak area to noise ratio (SNR) by fitting a voigt-lineshape model to the data and the absolute tCho levels using water signal as an internal reference [3]. Data for lipid peaks at 0.9 ppm (CH₂-) and 1.3 ppm (-(CH₃)₂) were also measured by fitting a Voigt-lineshape model, and a ratio of 1.3/0.9 ppm was calculated. Metabolite basis set signals (e.g., tCho, H₂O, and Lipids) were simulated in SIMULATION in jMRUI (e.g., S = S₀ × exp(-βt) × exp(iωt+φ₀)) and quantified with QUEST [4]. The CRLB for tCho peak were calculated, which is an estimate of the uncertainty in the peak amplitude determined by QUEST.

Results

Based on the morphological pattern of enhancements, all lesions were categorized into one of two groups: mass-type lesion and non-mass-type enhancements, according to the ACR BI-RADS lexicon [5]. Of 44 breast cancers, 31(70%) were mass-type cancer and 13 (30%) were non-mass type cancer. The mean lesion size was 3.7 cm (range, 1.6 – 8.6 cm) for the mass-type group and 4.0 cm (range, 1.5 – 8.0 cm) for the non-mass group (p = 0.660). Figure 1 and 2 show the representative examples of MRI and MRS measurements in a patient with a solitary mass and a patient with a non-mass displaying a regional enhancement pattern: (A) contrast-enhanced MR image, (B) delineated solitary mass, (C) water-fat suppression spectrum (128 averages) and (D) tCho signal detection after the removal of residual water (range, 4.0 – 6.0 ppm) and fat (0.0 – 2.6 ppm) components of the water-fat suppressed spectrum (128 averages). The Voigt model fitting of the tCho peak produces a measurement of SNR (40 vs.6.4) and tCho concentration levels (2.46 vs. 1.95 mmol/kg) in the mass and non-mass lesions, respectively. There was significant difference in tCho SNR level between mass-type and non-mass-type groups (p = 0.035). However, no significant group differences were observed in tCho concentration and lipids ratio of 1.3/0.9 ppm (p = 0.461 and 0.242), respectively. Table 1 summarizes in vivo breast ¹H-MRS results in the mass and non-mass groups.

Discussion

We investigated ¹H-MRS parameters for characterizing tumor morphological pattern of MR enhancements in breast cancer. The measured tCho levels in this work had a range of 0.1 from 10.5 mmol/kg from all 44 patients with malignant breast lesions, which were consistent with the previously published value (e.g., 0.09 – 10 mmol/kg). The CRLB for QUEST spectral fits were less than 25% for the tCho peak. The large range in tCho levels may reflect the intrinsic heterogeneous nature of breast lesions. When the malignant lesions were divided into mass and non-mass groups, the tCho concentration level was lower in the non-mass-type group than in the mass-type group, but not significant (2.06 vs. 2.50 mmol/kg, p = 0.461). However, the tCho SNR level was found to be much lower in the non-mass-type group compared to the mass-type group (e.g., about 45% less). This result reflects that tCho SNR measured by ¹H-MRS may be a good indicator to distinguish between mass and non-mass types. There was no significant change in CH₂/CH₃ peak ratio in between the two groups. The ratio of the peak areas indicate the length of saturated alkyl chain. The noticeable changes in the methylene signals were observed to accompany tumor evolution [6].

References

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