Proton-decoupled ^{13}C MRS of the Breast at 7T

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Introduction

Several studies indicate that composition of breast fat, which is sensitive to diet, may predispose to cancer [1]. The ω6/ω3 ratio might be particularly important [2]. Proton MRS at 7T has been used for fat composition determination in human calf muscle [3] and breast [4]. In human calf muscle it has also been shown [5] that ^{13}C MRS at 7T carries additional information compared to proton MRS, namely the ω6/ω3 ratio. Although substantial benefits in signal are anticipated at 7T [6], construction of safe and effective radiofrequency coils is a major challenge. In particular to achieve the full potential of ^{13}C MRS complete proton decoupling in the volume of interest is required. Correspondingly, to address the inhomogeneity in proton B_1 excitation profile at 7T and achieve proper proton decoupling in human breast, a "Forced Current Excitation" (FCE) technique was proposed [7]. This design uses transmission line properties to ensure equal coil element currents despite unequal loading, coupling, or coil sizes. The current work, using the FCE design demonstrates proton decoupled ^{13}C spectroscopy in the human breast, acquired at 7T.

Methods

Human experiments were performed using a protocol approved by the local IRB. Data were acquired on a whole-body 7T scanner (Achieva, Philips Medical Systems, Cleveland, OH, USA) using unilateral transmit/receive volume breast coil (^{1}H Helmholtz pair - two circular co-planar shielded loops [8] driven with FCE and ^{13}C saddle coil pair, each pair match and tune capable, Figure 1A). The FDTD electromagnetic modeling simulations were performed with Remcom XFdtd 7.1 software (Remcom, State College, PA) to obtain SAR calibration values. Coil performance and safety testing (via direct temperature measurements) was performed in phantoms. Localized (ISIS, 50x50x50 mm) ^{13}C spectra were acquired by averaging 64 acquisitions with TR 13 s for a total scan time of 14:44 min. One offset was used, centered on the CH_2 envelope of the fingerprint region (~ 29 ppm). WALTZ-16 decoupling with an 18 μT proton pulse centered at 1.3 ppm (for the fingerprint region) and NOE (10 μT at 5% duty cycle and a mixing time of 1.5 s) were used to simplify the spectra and enhance SNR. Scans were acquired with BW 16 kHz and 2k points.

Proton SVS MRS was acquired from a 5x5x5 mm voxel (positioned in breast fat tissue) with STEAM series of TE=27,28,29,30 ms, TR/TM=2500/23ms, BW 4kHz and 4k points, scan time of 3:30 min. A second acquisition followed with all selection and dephasing gradients inverted to eliminate frequency modulation sidebands caused by the large lipid peak at 1.3 ppm and eddy currents [4].

Results and Discussion

The FCE technique ensures uniform excitation, in turn helping to create a uniform proton excitation field (Figure 2). Excellent proton MRS data quality (Figure 3), allowed for calculation of diunsaturated, monounsaturated, and saturated fractions, giving results that are comparable to what was previously reported [4]. Broadband proton decoupled ^{13}C NMR spectrum from the right breast of a normal volunteer is shown in Figure 4, along with the data fit (blue). All expected major lipid ^{13}C peaks in the fingerprint region are observed, showing good decoupling and no detectable decoupling artefacts over the entire acquisition BW. In addition to the three fat fractions calculated from the ^{1}H spectrum, fitting the ^{13}C spectrum allowed us to calculate ω6/ω3 = 1.94.

Conclusions

In conclusion, artifact free proton-decoupled breast ^{13}C MRS at 7T was demonstrated for the first time. It has the potential to provide ω6/ω3 information on lipid composition, which may shed further light on the relations between obesity, diet, and cancer. Further improvements in ^{13}C coil sensitivities may be required in order to achieve higher SNR and shorter acquisition times.

Acknowledgments

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References

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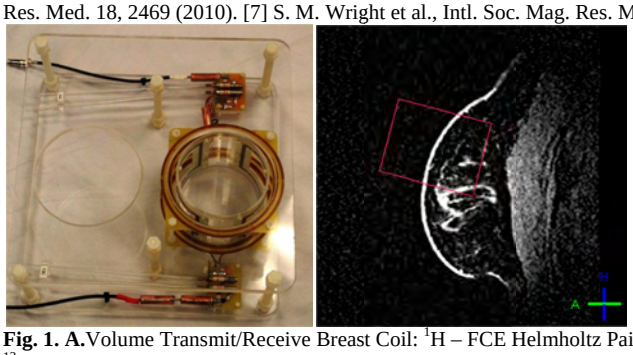

Fig. 1. A. Volume Transmit/Receive Breast Coil: ^{1}H – FCE Helmholtz Pair; ^{13}C – Saddle Pair. **B.** ISIS positioning on a FFE T_1W fat suppressed image.

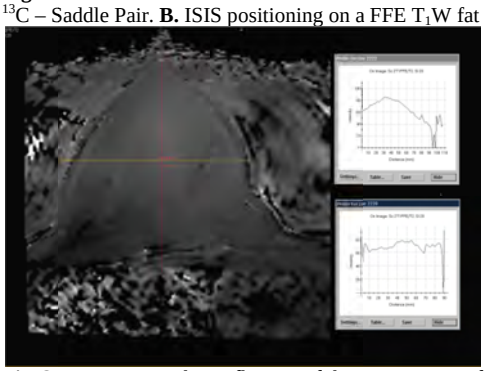

Fig. 2. B_1 mapping shows flatness of the excitation profile across the breast with approximately 1cm penetration into the chest wall.

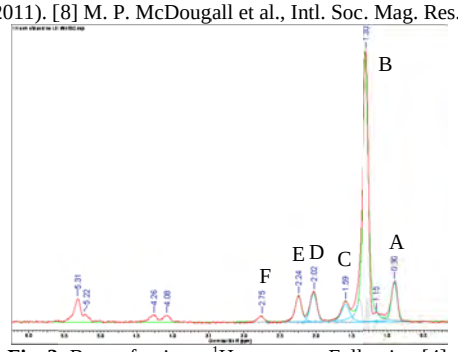

Fig. 3. Breast fat tissue ^{1}H spectrum. Following [4], polyunsaturated fraction was determined as F/E=0.22, monounsaturated as 0.5*D/E – F/E=0.42, and saturated as (1 – polyunsaturated – monounsaturated)=0.36.

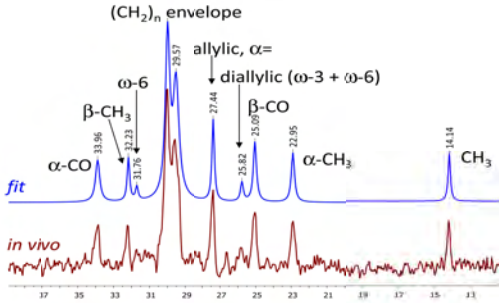

Fig. 4. The fingerprint region of the *in vivo* breast ^{13}C spectrum.