# Human Breast Lipid Composition Determination by *in Vivo* Proton MRS at 7T

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## INTRODUCTION

An issue of great interest to the public is the role of diet in the pathogenesis of breast cancer. Fat consumption is correlated with breast cancer mortality rates (1). Saturated fat in the diet weakly correlated with breast cancer (2) in one analysis, but in the Nurses' Health Study, intake of animal fat and high-fat dairy foods was associated with a significant increase in risk for breast cancer (3). These observations support the hypothesis that nutrition, specifically a diet high in saturated and monounsaturated fats, is an environmental determinant of breast cancer. Interventional studies tend not to support this hypothesis but the extent to which these diets actually change breast fat composition is not known. It has proven difficult to study the relation of breast fat composition to the risk of cancer with invasive biopsies, and the role of $^1$H NMR spectroscopy to detect tumor biomarkers is a promising area of research. Here we report on the non-invasive determination of lipid composition in human breast by proton MRS at 7T.

## METHODS

All spectra were acquired on a whole-body 7T scanner (Achieva, Philips Medical Systems, Cleveland, OH, USA) using a 10-cm diameter linear transmit/receive surface coil. The coil consists of a 1 mm-diameter silver wire segmented every 6 cm ($\lambda$/16) by 3.9 pF non-magnetic capacitors (ATC, Series B, Huntington Station, NY) and placed on a flexible Teflon former. Two variable capacitors (1-40 pF; Johansson, Camarillo, CA) were used for tuning and matching in a balanced configuration. To reduce power deposition in the patient, 1 cm$^2$ copper patches were placed on the former between the capacitors and the patient. The coil was padded with ~ 1 cm thick foam to reduce patient-induced losses by the lift-off effect. The coil was SAR modeled with FDTD for the breast configuration; heating tests on a human torso phantom were also performed to insure the coil's safety. All human volunteers were scanned with local IRB approval. Healthy volunteers (n = 5, age 28 ± 5 y) were positioned on their right side and the coil was placed under the right breast. Small (~150 ml) bags filled with $D_2O$ were placed both in the central opening of the coil as well as on the breast, on the side opposite the coil, to improve $B_0$ shimming. T2-w localization was performed to aid voxel placement. Voxels (10 x 10 x 10 mm$^3$) were placed in the outer regions of the breast (subcutaneous fat). For each voxel, two respiratory triggered STEAM acquisitions were performed where the second acquisition had all selection and dephasing gradients inverted. This was done in order to eliminate frequency modulation sidebands caused by the large lipid peak at 1.3 ppm. Each STEAM acquisition was a TE-averaged scan with four TE's - 23 to 26 ms, with 16 averages per TE. Other parameters were TM 20 ms, TR 2.5 s, no water suppression, BW 4 kHz, 4096 samples. The total scan time for the two STEAM series was about 10 min. $T_1$ and $T_2$ were measured (n = 2) using standard inversion recovery and echo-series sequences. All volunteers tolerated the exam well. After adding the two STEAM series, the data were phased, baseline corrected and fitted with Voigt lineshapes using ACD software (Toronto, Canada). Peaks were assigned and ratios quantified according to a previous study (4).

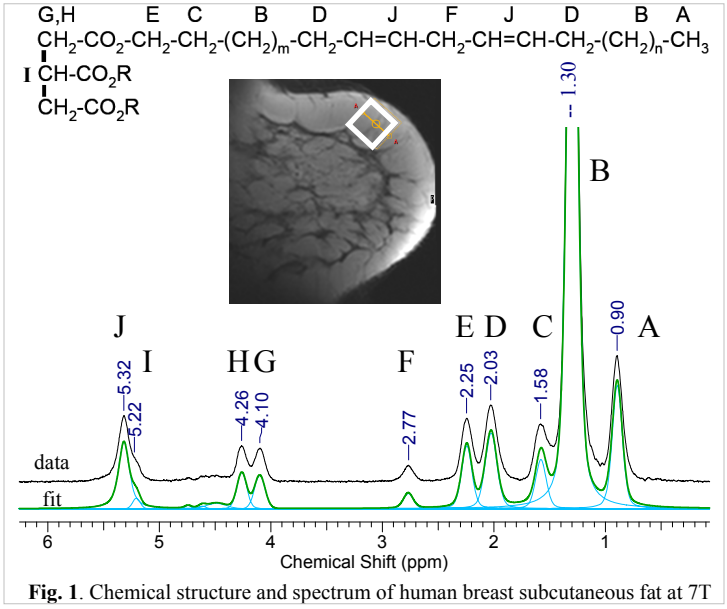


**Fig. 1**. Chemical structure and spectrum of human breast subcutaneous fat at 7T

| *Letter and Structure* | *Chemical Group* | *Chemical Shift, ppm* | *T1, ms* | *T2, ms* |
|---|---|---|---|---|
| A (methyl protons) | -C**H**$_3$ | 0.90 | 1071 ± 27 | 40.9 ± 18.2 |
| B (methylene protons) | -(C**H**$_2$)$_n$- | 1.30 | 549 ± 16 | 52.1 ± 16.8 |
| C (methylene protons β to COO) | -C**H**$_2$-CH$_2$-COO | 1.58 | 470 ± 15 | 39.6 ± 7.9 |
| D (methylene protons α to C=C) | -C**H**$_2$-CH=CH-C**H**$_2$- | 2.03 | 502 ± 11 | 32.0 ± 4.2 |
| E (methylene protons α to COO) | -C**H**$_2$-COO | 2.25 | 465 ± 22 | 36.3 ± 2.7 |
| F (diallylic methylene protons) | =CH-C**H**$_2$-CH= | 2.77 | 629 ± 72 | 39.8 ± 3.0 |
| G (methylene glycerol backbone) | C**H**$_2$-O | 4.10 | | |
| H (methylene glycerol backbone) | C**H**$_2$-O | 4.26 | | |
| I (methine glycerol backbone) | C**H**-O | 5.22 | | 43.9 |
| J (methine protons) | -C**H**=C**H**- | 5.32 | | 42.0 ± 19.2 |

## RESULTS AND DISCUSSION

Figure 1 shows a spectrum from subcutaneous fat of the breast. Ten lipid peaks were typically resolved with the methine glycerol backbone protons at 5.22 appearing as a shoulder on the methine protons of the double bond at 5.32 ppm, see the Table. The average lipid composition determined from all five subjects was 30.5 ± 9.5 % saturated, 48.4 ± 10.0 % mono-unsaturated, and 21.1 ± 2.0 % di-unsaturated fats. The $T_1$ and $T_2$ for the lipid peaks are also presented in the Table. The importance of respiratory triggering the scan is shown in Fig. 3, where pronounced fluctuations are seen if triggering is not applied. Although these fluctuations can be removed by postprocessing, this complicates the analysis of the data and was easily avoided by triggering.

In conclusion, we have shown that a chemical analysis of lipids in breast tissue can be determined quite simply and non-invasively by proton MRS at 7T.

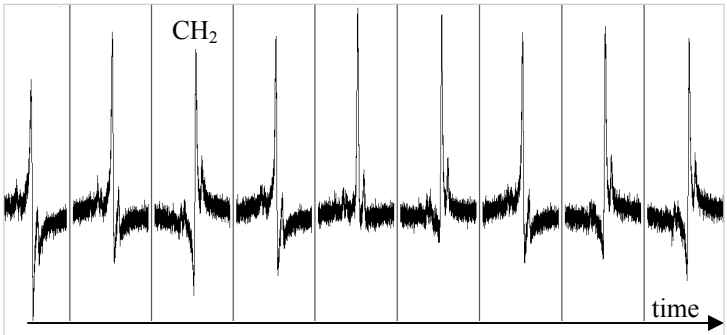


**Fig. 2**. Phase fluctuations caused by respiration. Spectra are separated by 3-5 s.

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