Resolution-enhanced MRS of red bone marrow fat via intermolecular double-quantum coherences in human knees

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Target audience: Basic scientists and clinical scientists who are interested in fat metabolism using MRS.

Instruction: It is known that the composition of fatty acid in red bone marrow is related to some obesity and hematopoietic diseases. The typical approach for fatty acid quantification is to aspirate the red bone marrow fat with a puncture needle for testing. As a noninvasive method, MRS has been used in monitoring metabolite profiles. However, the honeycomb bone structure in the bone marrow leads to serious inhomogeneities in the local B0 field, making it difficult to obtain well-resolved spectra using conventional MRS methods. Intermolecular double-quantum coherences (iDQC) 2D spectra technique has been shown to be insensitive to inhomogeneous B0 fields. Our previous findings using an iDQC MRS technique on 500 MHz spectrometer [1] and 7.0 T small animal MRI scanner [2] promote us to do a pilot study to establish whether this technique has beneficial effects for detecting the composition of red bone marrow fat in humans on a 3.0 T clinical scanner.

Theory: iDQC signal originates from the dipolar couplings between distant protons in the range of 5-1000 µm ("correlation distance"), thus only the magnetic inhomogeneous field in this range of the distance between interacting protons will broaden the line-width. If the correlation distance is set to about 50 µm at the cellular level, the local serious inhomogeneous B0 field caused by the trabecular bone theoretically will not affect the iDQC signal. Combined with a conventional localized module, resolution-enhanced spectra of red bone marrow fat may be achievable.

Method: The localized iDQC pulse sequence was shown in our previous study [2]. All experiments were performed on a 3.0 T Siemens Tim Trio human MRI scanner with a knee coil. A healthy 30-year-old female volunteer was scanned and the ROI for MRS was localized to her right knee (Figure 1. a). The scan parameters were: TR=3000 ms, TE=45 ms, ROI=60×60×40 mm^3, correction distance=50 µm, acquisition time=50 ms, F1=10 kHz. The methylene protons of fatty acid (1.3 ppm) were used to produce the dipolar field. After acquisition, the raw MRS data was first processed by regular Fast Fourier Transform and then an accumulated spectra of the cross-peaks was projected on to the F2 dimension after the streaks rotated by 63.4° with homemade Matlab-based programs. A conventional PRESS spectrum was also acquired for comparison.

Results and Discussion: As shown in Figure 1(d), conventional MRS has just three broad peaks: water, fatty acid peaks at1.3 and 5.3 ppm (which still overlaps on the water peak). In contrast, the accumulated projection 1D iDQC spectra (Figure 1. b) can resolve more fatty acid peaks. The methylene peaks (C and D) are well resolved from the main fat peak at 1.3 ppm and the fat peak at 5.3 ppm is separated from water completely. What is more, the diallylic methylene peak (E), which can be used to estimate the content of the polyunsaturated fatty acid, is much more prominent.

Conclusions: This pilot study proves that the localized iDQC technique can be used to enhance the spectral resolution of human red bone marrow fat on a 3.0 T scanner. Since the magnetic field strength of 3.0 T human scanner is lower than 7.0 T small animal scanner, the resolution of 1D iDQC projection spectra is not as good as we reported before in 7.0 T [2], in which the peaks C and D were also separated. However, compared with conventional MRS, localized iDQC technique can still enhance the fatty acid spectra resolution in red bone marrow, resulted in several well resolved fatty acid peaks, which may provide potential biomarkers for diagnostic purposes.

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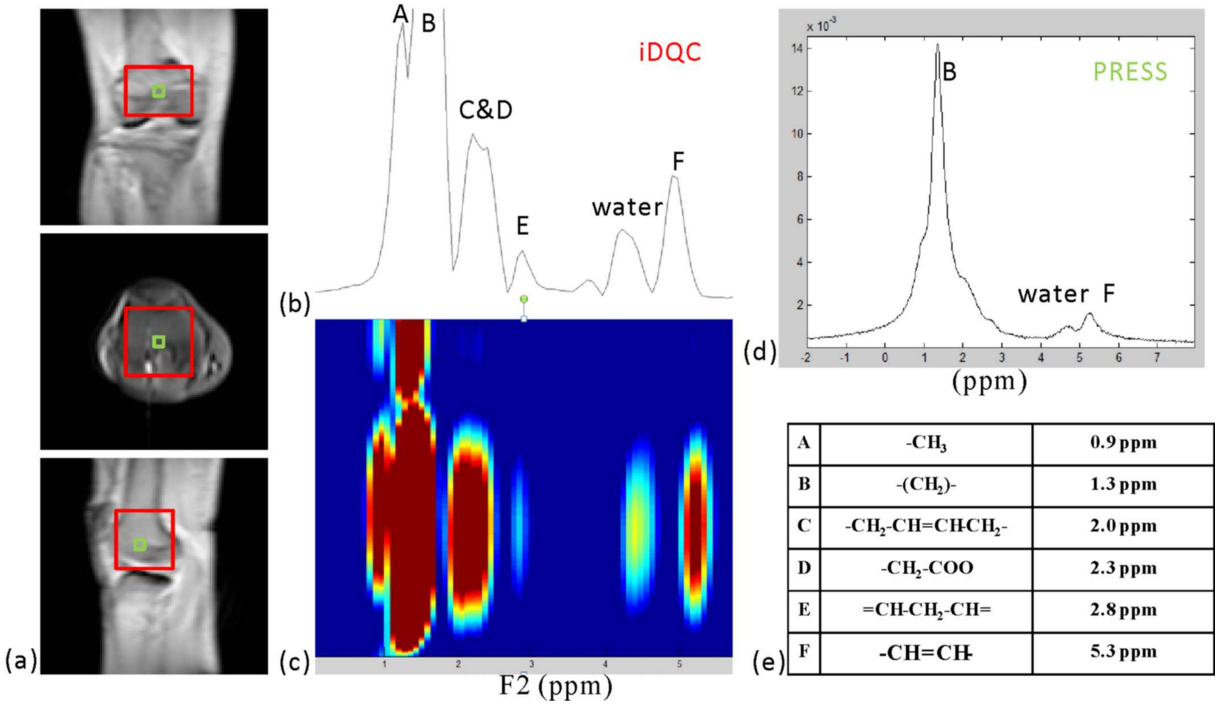

A	$-CH_3$	0.9 ppm
B	$-(CH_2)-$	1.3 ppm
C	$-CH_2-CH=CH-CH_2-$	2.0 ppm
D	$-CH_2-COO$	2.3 ppm
E	$=CH-CH_2-CH=$	2.8 ppm
F	$-CH=CH-$	5.3 ppm

Figure 1. (a) Voxel position displayed in anatomical images of the knee. The red box shows the localized iDQC and small green box is for conventional PRESS. (b) Accumulated projection resolution-enhanced spectra from the rotated iDQC spectra (c). (d) Compared 1D spectra obtained by PRESS. (e) Chemical shifts of different fatty acid protons.

Reference:

[1] Z. Chen, et al. J. Chem. Phys. 130, 084504 (2009). **[2]** J.F. Bao, et al. 21st ISMRM meeting, 2013#4042, Salt Lake City, Utah, 2013