High-resolution localized ^{1}H magnetic resonance spectroscopy of red bone marrow via iDQC technique at 7T

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TARGET AUDIENCE

The target audience is basic scientists and clinical scientists who are interested in high-resolution localized ^{1}H magnetic resonance spectroscopy (MRS) and in monitoring the progress of hematopoietic diseases through MRI.

PURPOSE

Red bone marrow is the principal organ that forms blood cells in mammals. The composition in red bone marrow has been proved to be associated with leukemia, cardiovascular disease, insulin resistance, etc.[1] Clinically, puncture biopsy remains a gold standard for evaluating and diagnosing red bone marrow disease. Localized ^{1}H MRS is a noninvasive method that has been widely used to measure the concentration of metabolites. MRS has been applied to the studies of red bone marrow as well. However, due to the bone trabeculae structure and the mixture of water and fat protons within a very small scale, the local B_0 field within the red bone marrow is very inhomogeneous in nature. Thus, common localized ^{1}H MRS can only give two rough peaks, one is from water and the other is from the methylene of fat. Other protons especially the unsaturated fat protons, which may provide more diagnostic information, are not well resolved. In this abstract, we present a new localized ^{1}H MRS method based on intermolecular double-quantum coherence (iDQC) technique to achieve high-resolution ^{1}H MR spectra of red bone marrow.

METHODS

The iDQC technique can be used to detect the correlation between spatially separated protons. The iDQC signal is not affected by the field inhomogeneity beyond the distance of correlation protons. This distance is called correlation distance and can be controlled from 10 mm - 10 μm. Theoretically, if the correlation distance is smaller than the cell size of the red bone marrow, the effect of macroscopical B_0 inhomogeneity can be overcome. On the other hand, the field inhomogeneity within the correlation distance will still affect the signals and result in spectral line broadening.

The pulse sequence for localized iDQC ^{1}H MRS is shown in Fig. 1. A pair of pulse field gradients (G & 2G) is used to select iDQC signals and regulate the correlation distance (25 μm in this wok). The second π/2 pulse is Guass shape and is used to selectively excite certain kinds of protons to generate dipolar field. A PRESS module is used for localization. The sample was a pig vertebra bought from a market. All the experiment was performed on a 7 T small animal scanner.

The obtained 2D iDQC spectrum was counterclockwise rotated by 63.4° along the F1 dimension, and then projected onto the F2 axis to provide a high-resolution 1D iDQC spectrum.

RESULTS AND DISCUSSION

Figure 2a shows the axial image of the pig vertebra and the box shows the localized regions. Figure 2b and c show the 2D localized iDQC spectrum, and differently, the methylene protons of fat (-CH_2-, 1.3 ppm) are used to generate dipolar field in Fig. 2b and the water protons are used to generate dipolar field in Fig. 2c. Figure 3a shows the standard ^{1}H PRESS spectrum, where only two broad peaks (water at 4.8 ppm and fat at 1.3 ppm) can be resolved. In contrast, six additional fat peaks can be resolved in the 1D projection of the rotated 2D spectrum (Fig. 3b-3d). In Fig. 3b, the olefin peak is well distinguished from the water peak. In Fig. 3c, the polyunsaturated protons of fat (3.0 ppm) can be detected. In Fig. 3d, more fat peaks are well resolved from the methylene. Since dipolar correlation distance is very small (25 μm), water proton lack nearby methylene protons inside correlation distance, the iDQC water signal can be naturally suppressed, [2] as shown in Fig.3b.

It should be noted that because the correlation selection gradients and selective pulse are employed in our pulse sequence, the relative proportion of the peaks is not the same as in standard 1D spectrum, thus an extract of red bone marrow is necessary to correct our results. Additionally, large voxel is necessary for good signal to noise ratio, so our method is not suitable for small animals like the rats. But for human, large voxel is not a problem. Since 2D acquisition is employed, the scanning time is about 17 min. More fast 2D technique, like Hadamard encoded or spatial encoding technique is being tried to speed up scanning.

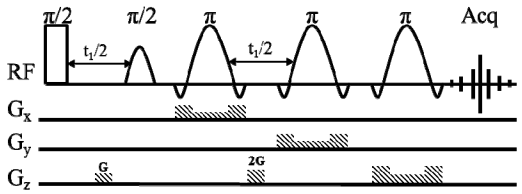

FIG. 1. Pulse sequence for localized iDQC MRS

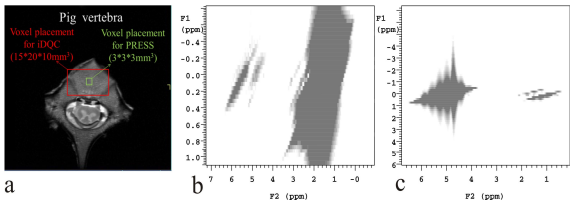

FIG. 2. **(a)** Axial MRI slice image of a pig vertebra; **(b & c)** localized 2D iDQC spectra of the vertebra with methylene protons (-CH_2-) coupled with other protons **(b)** and with water protons coupled with other protons **(c)**.

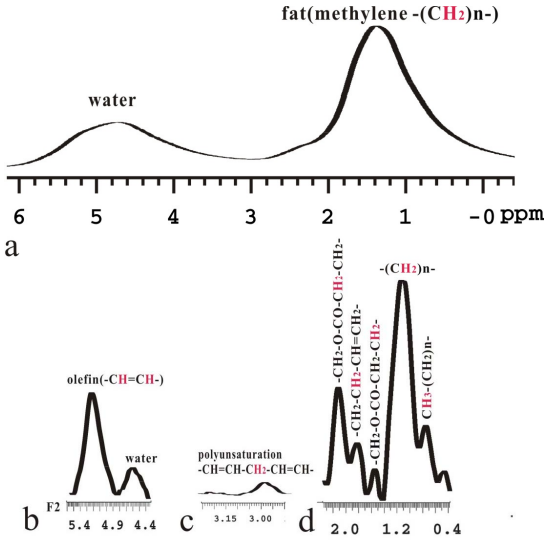

FIG. 3. **(a)** Standard localized PRESS spectrum; **(b-d)** fragments of accumulated projection of Fig. 2b **(b & c)** and Fig. 2c **(d)** along the F2 dimension after counterclockwise rotation of 63.4° separately.

CONCLUSION

The feasibility of localized iDQC technique for high-resolution MR spectrum of red bone marrow was proved for the first time. This method can be used to detect and monitor the lower concentration compositions in red bone marrow.

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