Assessment of myocardial triglycerides by 2D PRESS echo-planar spectroscopic imaging

Jan Weis[1], Morten Bruvold[2], Francisco Ortiz-Nieto[1], and Håkan Ahlström[1]
[1]*Department of Radiology, Uppsala University Hospital, Uppsala, Sweden,* [2]*Philips Healthcare, Best, Netherlands*

Introduction

^{1}H single-voxel spectroscopy has shown usefulness in the assessment of myocardial fat content in healthy volunteers; fat over-storage in over-weight/obese subjects; in patients with impaired glucose tolerance; and, in patients with type 2 diabetes mellitus [1-3]. Single-voxel MRS is restricted to a relatively large voxel size (~10x10x30 mm^3) and position within the intraventricular septum. Spectra from voxels projected onto other parts of the heart are usually contaminated by epicardial fat [1]. Solution of these limitations could be high spatial resolution echo-planar spectroscopic imaging (EPSI). Recently, cardiac and respiratory motion gated EPSI was proposed [4]. Additional regional saturation slices (REST) were needed to suppress signal folding from outside the heart. The problems with signal folding can be avoided by PRESS volume of interest excitation (VOI). The purpose of the present work was to introduce PRESS EPSI technique for the assessment of triglyceride (TG) content in the human myocardium.

Materials and Methods

Following informed consent, a normal healthy human male volunteer, aged 60, with normal body mass index of 24.5 kg/m^2, was measured with a 3 T scanner (Achieva, Philips Healthcare), using a circular, two-element receiver surface coil (Φ = 20 cm). The echo-planar readout gradient train was implemented into a standard spectroscopic imaging PRESS pulse sequence. 2D PRESS EPSI measurement was performed by means of 64x64 spatial matrix (Fig. 1); nominal voxel size 3x3x15 mm; acquisition bandwidth 128 kHz; and, TE = 33 ms. Magnetic field homogeneity was improved using iterative first order shimming. Water suppression was performed using band-selective pre-pulses. The sequence was double triggered, utilizing the ECG and a pressure belt for respiratory gating. ECG triggering was defined to the middle of diastole (740 ms). Mean repetition time was ~5 sec, depending on the breathing period. REST slices were omitted. One and three signal averages were used for non-water and water suppressed scans, respectively. The acquisition with two interleaved gradient echo trains was performed in order to increase spectral bandwidth. Beginning of the second gradient echo train was shifted about half period (0.8054 ms) of the readout gradients. Combination of both echo trains resulted in the spectral bandwidth 9.72 ppm. 128 echoes arising from positive and negative readout gradients were processed for each element of the receiver coil separately, i.e., four (k-read, k-phase, k-t) = (64, 64, 128) data matrices were processed. Measured matrices were zero-filled to size (64, 64, 512). Data processing began with optimized 2D Hanning filter [5] applied across the k-read and k-phase dimensions to reduce signal bleeding. The first FFT was performed along the k-t axis. Chemical shift artifacts caused by readout gradients were removed using a first-order phase corrections [6]. Data processing continued with 2D FFT along k-read and k-phase axis. Magnitude spectra of resulting four spectral matrices were then averaged. Averaging of real spectra is practically impossible because large quantities of voxel spectra cannot be reliable phase-corrected before summation. The spatial distribution of the magnetic field ΔB in the measured slice was computed from the position of the highest spectral line of non-water suppressed spectra. Voxels spectra were then shifted about $\Delta B/B_0$ along the spectral axis. Magnitude spectra were averaged from each VOI (Fig. 2b) and fitted without pervious noise suppression, by AMARES algorithm within the jMRUI [7, 8]. Complex input FIDs, for jMRUI, were computed by inverse FFT of the magnitude spectra [9]. The TG content was estimated as the ratio of the TG intensity at ~1.3 ppm to the water x100%. Relaxation corrections of water and TG intensities were done using $T1_W$ = 1471 ms, $T2_W$ = 47 ms, $T1_{TG}$ = 382 ms, and $T2_{TG}$ = 68 ms [10, 11].

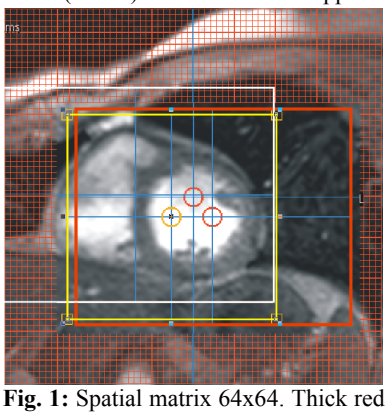

Fig. 1: Spatial matrix 64x64. Thick red and white rectangles show lipid (CH_2) and choline PRESS boxes, resp. Yellow line depicts shimming volume.

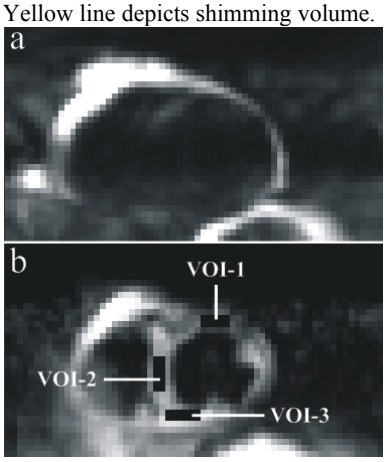

Fig. 2: Image of fat (a) and water (b) spectral line integrals. VOIs are marked by black rectangles.

Results

Figure 1 shows position of measured spatial matrix and excitation volumes (PRESS boxes) of TG (CH_2) and choline resonances. Epicardial fat and water images are shown in Fig. 2. Figure 2b shows the VOIs. Unsuppressed water lines and TG spectra are shown in Fig. 3. The estimated percentage of myocardial triglyceride content was 4.5%, 0.7%, and 1.8%, for VOI-1, -2, and -3, respectively.

Discussion

PRESS EPSI sequence was used for the first time in estimation of the myocardial triglycerides. The PRESS VOI selection enables smaller FOV without the need REST slices to suppress signal contamination from outside the VOI. Although simple respiratory triggering was used, the quality of our spectra is comparable with those measured using more sophisticated navigator gating [4]. Myocardial TG content originated from VOI-2 and 3 is in good agreement with the single-voxel MRS estimations [2, 3]. Increased TG content in VOI-1 can be explained by signal contamination from epicardial fat (Fig. 2a), due to thin cardiac wall and large slice thickness (15 mm).

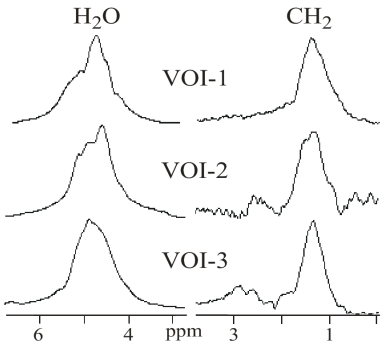

Fig. 3: Unsuppressed water and TG spectral lines.

Conclusion

This study has demonstrated that ECG and respiratory triggered PRESS EPSI is an effective tool for assessment of myocardial TG content. The data processing approach using magnitude spectra avoids the need for individual phase correction before voxel spectra averaging. High spatial resolution enables evaluation of local myocardial triglyceride changes in non-continuous and irregularly shaped volumes of interest.

References

[1] Szczepaniak LS et al., MRM 49:417, 2003. [2] v. d. Meer RW et al., Radiology 245:251, 2007. [3] McGavock JM et al., Circulation 116:1170, 2007. [4] Weiss K et al., Proc ISMRM 19:620, 2011. [5] Pohmann et al., MRM 45:817, 2001. [6] Weis et al., MRM 41:904, 1999. [7] Narresi A et al., MAGMA 12:141. 2001. [8] Vanhamme I et al., JMRI 129:35, 1997. [9] Weis J et al., MRM 57:22, 2007. [10] Stanisz GJ et al., MRM 54:507, 2005. [11] de Bazelaire CMJ et al., Radiology 230:652, 2004.