Multi-channel Proton Spectroscopy of the Heart

N. Martini[1], K. Weiss[2], P. Boesiger[2], D. Chiappino[1], and S. Kozerke[2]
[1]Fondazione G. Monasterio CNR-Regione Toscana, Massa, Italy, [2]Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Switzerland

Introduction

Single-voxel (SV) proton magnetic resonance spectroscopy (^{1}H-MRS) has been shown to be a valuable tool for the non-invasive assessment of myocardial triglycerides (TG) [1]. Traditionally, single-element coils are used for signal reception. However, because of their limited spatial sensitivity, the accurate positioning of the coil element close to the region of interest, i.e. the heart, can become critical when optimizing signal-to-noise ratios (SNR) [1]. The use of multi-element receiver coils offers high sensitivity over large field-of-views. Within this context, optimal combination of the individual MRS signals is required to maximize the SNR. The purpose of the current work was to investigate the use of phased array coils for navigator gated and ECG triggered cardiac ^{1}H-MRS. Suitable reconstruction of cardiac MRS signals from multiple receiver elements is introduced and experimental results with 5-element and 32-element arrays are presented.

Materials and Methods

Experimental studies were performed on six healthy volunteers using a 1.5T Philips Achieva system (Philips Healthcare, Best, The Netherlands). A short echo time (TE = 33 ms) Point Resolved Spectroscopy (PRESS) sequence was used for volume localization in the interventricular septum. Pencil beam navigation was implemented for respiratory motion compensation [2]. Prior to data acquisition automatic shimming of the single voxel using breath hold and water suppression optimization using navigator triggering was performed. Data acquisition was ECG triggered to the end-systolic phase, the minimum repetition time (TR) was set to 2000 ms and the voxel size was 10mm x 20 mm x 40mm. A total of 8 water-unsuppressed scans and 128 water-suppressed scans were acquired resulting in an overall scan time of about 13 minutes depending on heart rate and respiratory gating efficiency. Both the 5-element and 32-element cardiac coil array were used for signal reception in the same session. For each dataset, offline reconstruction of multi-channel MRS data was performed using Matlab software (The Mathworks, Natick, USA) according to the scheme shown in Figure 1. Noise covariance matrices were estimated from a pure noise scan and were used to decorrelate the noise between channels [3]. Linear combination of the coil element signals was performed with the SNR weighting approach [4]. The phase and the amplitude of the water peak in the water-unsuppressed spectra were used to determine the complex weighting factors. Background noise was estimated in the spectral regions without signal. Individual SNR weighted coil signals were then iteratively added until the SNR of the water spectrum reached the maximum value (SNR_{5CH} and SNR_{32CH}). The same set of coils was then used to reconstruct the water-suppressed spectra. In addition, phase correction of individual acquisitions was done before coherent averaging to account for residual motion-induced phase fluctuations [5]. Water-unsuppressed and water-suppressed spectra were fitted using the jMRUI software [6] to estimate the water and the TG signals, respectively. The amplitude of the TG peak divided by the amplitude of the water peak was computed to yield percentage of myocardial TG content. Correction for the different T1s of water and TG signal was done using $T1_W$=1100 ms, $T1_{TG}$=280 ms [7].

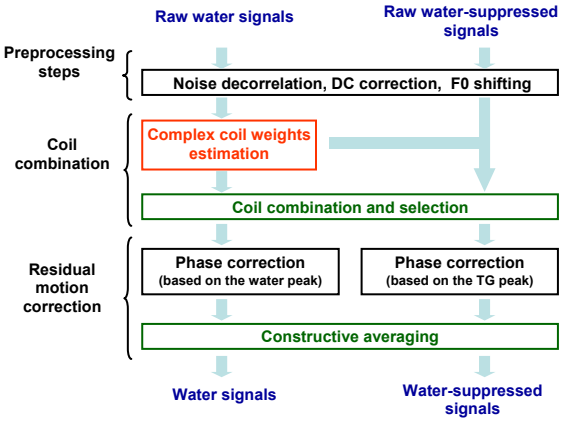

Fig. 1 Reconstruction steps of multi-channel MRS data.

Results and Discussion

On average, the SNR of the water peak of the 32-element array data was higher compared to the one of the 5-element array data (SNR_{32CH} /SNR_{5CH} = 1.74 ± 1.00, mean ± SD across subjects). A representative example of the results obtained with both coil arrays in the same subject is shown in Figure 2. The line width of the water peak was 10 Hz in both cases. Spectral quality of the water-suppressed scans allowed visualizing the myocardial triglyceride peak (TG) at 1.3 ppm as well as the creatine resonance (Cr) at 3.02 ppm. The SNR of the TG peak was lower using the 5-channel relative to the 32-channel array (17 against 23). The estimated percentage of TG content was 0.61% and 0.73% with the 5-element and the 32-element array, respectively. This small difference in the estimated TG content could be related to some residual incoherent averaging in the 5-element water-suppressed data, since the lower SNR of the TG peak may have caused phase correction errors.

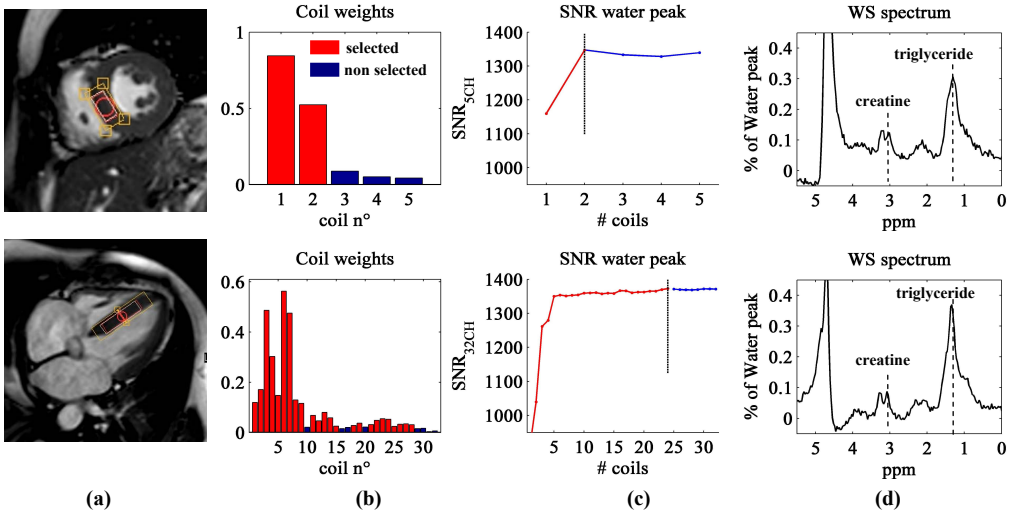

Fig. 2 (a) Voxel position (small box) and shimming volume (larger box) in short-axis and four chamber views. (b) Amplitude of the coil weighting factors. (c) SNR of the water spectrum as a function of the number of elements used. (d) Water-suppressed spectra. For visualization purposes, spectra are normalized to the water peak amplitude. Upper panels of (b), (c), (d) are based on 5-element coil array data, while lower panels show the 32-element array data.

Conclusion

In summary, this study has demonstrated the feasibility of cardiac ^{1}H-MRS using large coil arrays. A general workflow for the reconstruction of multi-channel cardiac MRS data has been developed. Future work will be focused on investigating the reproducibility of this approach in the quantification of myocardial triglyceride and creatine content.

References

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