1H Liver Spectroscopy with 32-Element Coil Arrays

T. Schirmer[1], D. K. Sodickson[2], N. M. Rofsky[2], H. Cline[3], C. J. Hardy[3], M. Thormann[4], F. Fischbach[4], H. Bruhn[4], J. Ricke[4], T. Niendorf[5]

[1]Applied Science Laboratory, GE Healthcare Technologies, Hallbergmoos, Germany, [2]Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, Massachusetts, United States, [3]Global Research Center, General Electric, Niskayuna, New York, United States, [4]Campus Virchow Klinikum, Charité Berlin, Berlin, Germany, [5]Applied Science Laboratory, GE Healthcare Technologies, Boston, Massachusetts, United States

Introduction

Abdominal proton spectroscopy has been proven to be of clinical value, which prompted the development of numerous new applications including liver spectroscopy [1, 2]. For clinical acceptance liver spectroscopy requires an acquisition and processing protocol, which is easy to use in a clinical setting while providing robust spectral quality. The low concentration of metabolites other than lipids and the respiratory motion of the liver dictate rapid acquisition of the spectra while preserving high SNR. This study demonstrates the feasibility of single voxel liver spectroscopy at 1.5 T using a multi-channel receiver system with many element coil arrays which to provide spectral quality significantly superior to that achievable with a body resonator used in recent 3T studies [3]. The merits and limitations of the single voxel approach used in this study, as a precursor of accelerated spectroscopic imaging facilitated by multi-dimensional coil arrays, are discussed and implications for clinical applications and tailored coil designs are considered.

Methods

All experiments were performed on a GE Signa Excite 1.5T MRI Scanner (GE Healthcare Technologies, Milwaukee, WI, USA) equipped with a 32-channel acquisition system [4, 5] using three different coils: (i) the integrated body transmit/receive volume resonator (ii) a rigid lightweight 32-element coil array, tailored for small cardiac or abdominal fields of view and (iii) a flexible 32-element array, developed for large-volume abdominal imaging. Both arrays are comprised of two separated clamshells. The rigid 32-element array contain 21 anterior and 11 posterior elements. The flexible 32-element abdominal array uses 16 elements each for the anterior and the posterior segment. For the volunteer studies the posterior clamshell was placed underneath the subject, while the anterior segment was positioned on the subject's chest as shown in Fig. 1. A single voxel spectroscopy sequence with PRESS localization was developed, capable of running fully synchronized acquisitions for all 32 receive channels, which were distributed over four 8-channel receive systems [4, 5]. Localized PRESS spectra were acquired at a central location of the liver as illustrated in Fig.2. A short echo-time of TE=35ms was chosen so as to enhance lipid signal, since lipid is known to have short T_2 relaxation times. A 26 sec breath-hold exam was prescribed using TR=1200 ms, two dummy acquisitions, four unsuppressed water reference lines, and 16 water-suppressed averages obtained from an 8ml voxel. Six consecutive short breath-hold acquisitions were performed to achieve a total sum spectrum of 96 averages, and both single-breath-hold and six-breath-hold results were compared for the three coils.

All raw data were processed off-line on a Linux PC using a dedicated software package SAGE (GE Healthcare Technologies, Milwaukee, WI, USA). Prior to the recombination of the spectra from each coil element, phase and frequency were individually corrected based on the unsuppressed and the residual water signal. The individual spectra from the different coil elements were recombined using the unsuppressed water signal to determine the local coil sensitivity. The total sum FID was calculated by a weighted average of the time domain data based on the previously determined coil sensitivity. Subsequent processing included eddy-current correction, 2.0 Hz Gauss filtering, 40Hz high-pass filtering to remove unwanted residual water signal, and zero-filling to 8192 points prior to the FFT. SNR was estimated based on the amplitude of the lipid signal and the coefficient of variation of a potential noise area [6, 7].

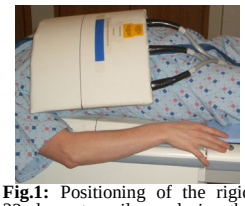

Fig.1: Positioning of the rigid 32-element coil used in the volunteer study (21-element coil segment is placed on top)

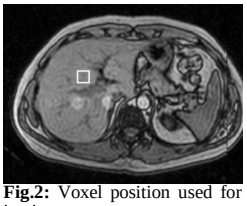

Fig.2: Voxel position used for in vivo spectroscopy.

Results

Liver spectra were successfully acquired and reconstructed for all coils used in this study as shown in Fig. 3. The qualitative as well as the quantitative results shown in Fig. 3 clearly demonstrate the SNR advantage of the 32-element coil arrays over the volume body coil. Using the body coil spectrum with 96 averages as a reference, the SNR of the coil arrays achieved in a single breath hold was still significantly superior to that derived from the body coil using multiple breath-hold acquisitions. For this deep-lying liver voxel, the SNR of the flexible 32-element abdominal coil array was approximately two fold higher than that achieved with the rigid 32-element array, which was originally designed for cardiac imaging with more modest fields of view.

Discussion and Conclusions

Robust clinical abdominal spectroscopy is generally challenging due to the poor spectral quality caused by respiratory motion, local magnetic field inhomogeneities and low metabolite concentrations. The main prerequisites for recording high quality abdominal spectra are (i) rapid data acquisition, ideally completed in a single breath-hold to avoid voxel misregistration and (ii) the use of high sensitivity coils. The liver spectroscopy study presented here indicates that the use of many element coil arrays, like the flexible and rigid 32-element arrays used here, provides the required signal sensitivity to acquire high quality spectra in a single breath-hold. In contrast, current body coil acquisitions require multiple breath-holds. If spectra obtained from several consecutive breath-holds using the 32-element arrays are averaged, an outstanding spectral quality can be achieved. For example the flexible coil array revealed a spectrum with a relative SNR of 864 as compared to the volume body coil SNR of 100 as shown in Fig. 3. Alternatively, the fundamental SNR gain in conjunction with the two-dimensional array design can be also used to apply spectroscopic imaging techniques to improve the spatial resolution in liver spectroscopy. Unlike the single voxel approach used in this study spectroscopic imaging offers the potential for accelerated scans using parallel imaging strategies. Our study also shows that coil design has a significant impact on the spectral quality. For example a many element coil array might provide excellent image quality for accelerated imaging due to SNR and noise amplification optimization but might be suboptimal for abdominal spectroscopic studies due to depth penetration or B_1 inhomogeneity constraints. In conclusion, future many element array designs should consider the characteristics of liver/abdominal spectroscopy and ideally combine them with the imaging requirements.

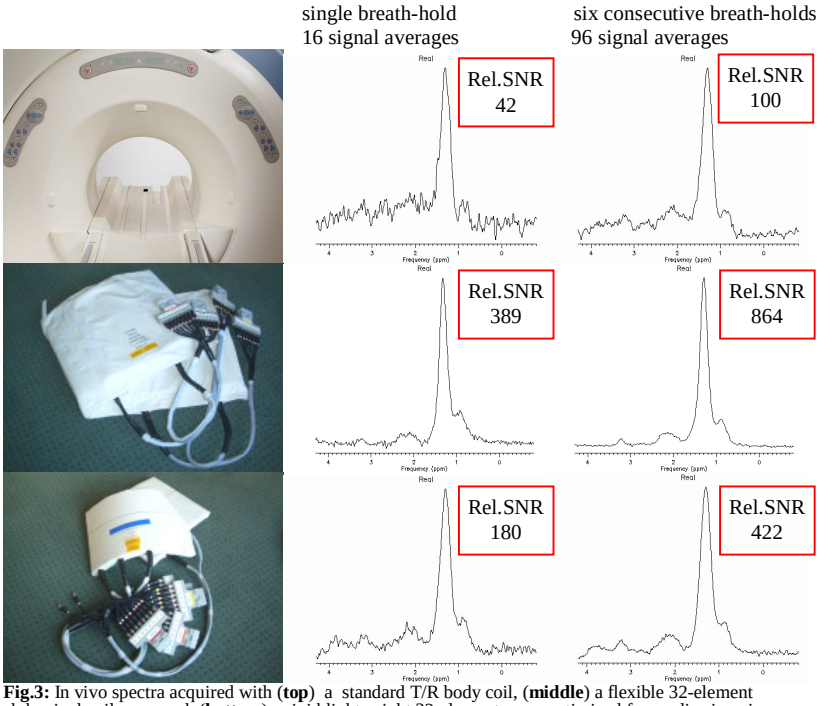

Fig.3: In vivo spectra acquired with (**top**) a standard T/R body coil, (**middle**) a flexible 32-element abdominal coil array and (**bottom**) a rigid lightweight 32-element array optimized for cardiac imaging.

References

[1] Tyszka JM et al. MagnResonMed 1998 ; 39 :1-5., [2] Dixon RM et al. Magn.Reson Med 1995 ; 31 :482-487., [3] Schirmer T et al. Proceedings of the ISMRM ; 2004, [4] Zhu Y. et al., Magn Reson Med 2004;52(4):869-77 ,[5] Hardy, C.J. et al., Magn Reson Med 2004;52(4):878-84, [6] Katz-Brull R et al. Magn.Reson.Med. 50:461-467 (2003), [7] Operator Manual for Signa MR/i Systems, GE HealthcareTechnologies, WI, USA