In vivo 1H CSI in the abdomen with Free-breath Prospective Acquisition Correction

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Introduction

Subject or organ motion during data acquisition is well recognized as a source of artifacts in magnetic resonance (MR) imaging as well as MR spectroscopy. Chemical shift imaging (CSI) has long been used in intracranial clinical applications that are not affected by significant motion, or in abdominal and cardiac 31P MR spectroscopy studies using physiological gating as a way of reducing motion artifacts. For abdominal spectroscopy measurements, respiratory gating requires monitoring of the breathing motion via a belt wrapped around the patient's abdomen, which is uncomfortable and may not be suitable for some patients. The newly developed 2D PACE (Prospective Acquisition Correction) 1H CSI technique is a more comfortable and clinically practical alternative for minimizing motion artifacts and improving spectral quality in the abdomen. 2D PACE was implemented in single voxel spectroscopy of the liver [1] allowing the detection of small metabolite peaks, which are not seen on free breathing or breath-holding spectra. In CSI in addition to reducing spatial misregistration, 2D PACE is expected to minimize the effect of respiratory motion on the point spread function (PSF) and reduce voxel bleeding.

Materials and Methods

A 2D PACE scheme was incorporated into a CSI SE (spin echo) sequence with triggering at the quiet end expiration phase of the respiratory cycle using a pre-defined acceptance window. The acceptance window is determined by the vertical width of the displacement of the diaphragm. Prior to the MRS measurement 2D PACE acquires fast gradient echo images while the patient is breathing freely. After a short "learning phase", the patient's breathing pattern is analyzed and the central position of an "acceptance window" is automatically calculated. The real time evaluation of the navigator signal allows for immediate start of the spectroscopic data acquisition as soon as the diaphragm has reached a position within the acceptance window. The navigator image needed for this determination is acquired in 100ms by means of a low-resolution gradient echo sequence featuring a low flip angle, which leaves the magnetization in the volume of interest practically undisturbed. This ensures that the magnetization is almost unsaturated. To minimize tissue displacement during the spectroscopic data acquisition, only one CSI echo is measured within a breathing cycle. This on the other side prolongs the measurement time with a resulting TR of about 3 to 4s (breathing cycle). To reduce the scan time elliptical scanning and acquisition weighting [2] was implemented in the PACE CSI sequence.

1H MRS measurements were performed in the liver of healthy volunteers on a Siemens MAGNETOM 3T Trio scanner using a phased array body coil and 2D CSI with and without 2D PACE. Acquisition parameters were: TE= 30 ms, slice thickness 20 mm, in plane resolution 15mm x 15mm, averages 3 (acquisition weighted), bandwidth 2kHz , total acquisition time ~3 minutes. Figure 1 displays positioning of the 2D PACE tracking voxel placed above the CSI slice and overlapping the liver and the lung. The middle graph illustrates positioning of the CSI VOI and the last graph displays the respiratory curve with the acceptance window. For the same volunteer data were collected with and without 2D PACE using the same measurement parameters. The non triggered measurement was acquired with a TR equal to the effective TR of the PACE measurement. Data processing was performed automatically with the Siemens spectroscopy post-processing software.

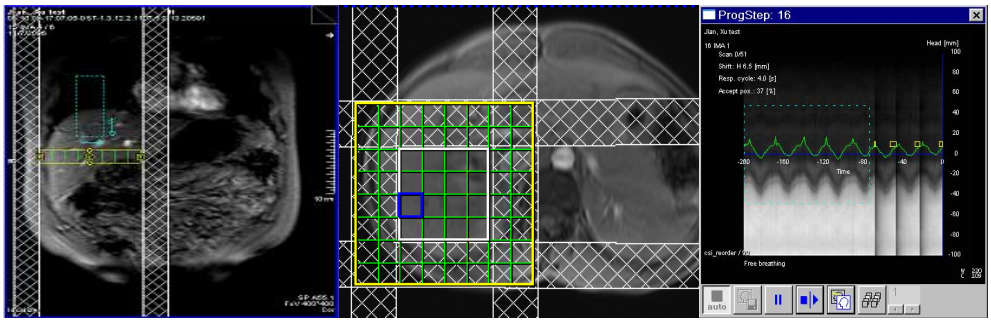

Figure 1: Left: Selection of the 2D area (blue dashed box) used for detection of the diaphragm position. Half the rectangle is within the lungs, and the other half is within the liver. Middle: Placement of the CSI VOI and 4 outer volume saturation slabs in the liver. Right: Projection of the navigator image plotted over time. The (green) curve shows the calculated respiratory motion. The height of the small (yellow) boxes shows the accepted motion tolerance.

Results and Conclusion:

Volunteer liver spectra from the same CSI voxel acquired with and without 2D PACE are shown in figures 2. The 2D PACE CSI spectra clearly have narrower and better defined peaks. Those include the lipid peaks at 0.9 ppm, 1.2ppm and 2-2.3 ppm, the peak at 3.2 ppm from choline and betaine and the peak at 3.7ppm assigned to glycogen. The lipid peaks are not resolved and glycogen is not seen in the spectra acquired without 2D PACE. These results demonstrate that 2D PACE CSI like 2D PACE SVS significantly improve the quality of clinical MRS studies in the abdomen while providing a practical and comfortable way for minimizing respiratory motion artifacts.

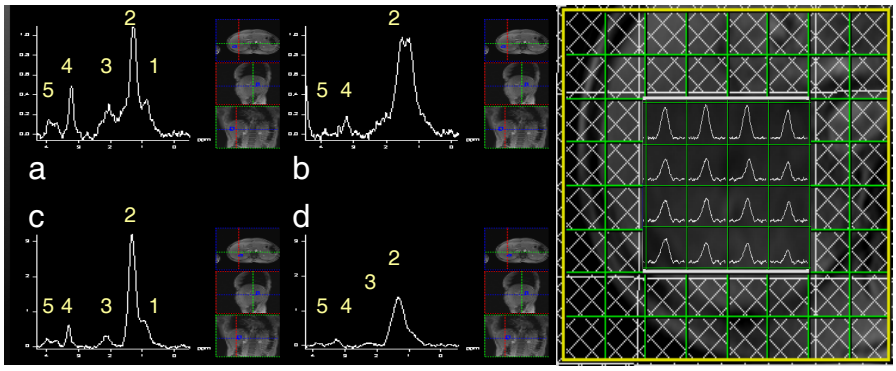

Figure 2: In vivo localized 1H 2D CSI volunteer liver spectra acquired at 3T with (a and c) and without (b and d) 2D PACE and with the same parameters: TR = 4500 ms, TE = 30 ms, bandwidth= 2000 Hz, 3 averages, 8x8x1 matrix, The 2D PACE spectra (a, c) are from two different voxels of the CSI grid. They have better defined and narrower peaks than the corresponding non 2D PACE spectra. Peaks 1, 2 and 3 are from lipids, peak 4 is from choline and betaine, and peak 5 is from glycogen. Peaks 1, 3 and 5 are not distinct on the non 2D PACE (b and d) spectra. Right: the choline spectral mapping.

Reference:

[1] J. Xu et al. In vivo 1H Liver Spectroscopy with Free Breathing 2D PACE. ISMRM 14th scientific meeting Seattle 2006.

[2] Pohmann R, von Kienlin M. Accurate phosphorus metabolite images of the human heart by 3D acquisition-weighted CSI. Magn Reson Med 2001;45:817–826.