Respiratory Motion Correction for 31P Spectroscopy in the Left Lobe of the Liver

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Introduction:

31-phosphorus (^{31}P) MR spectroscopy (MRS) allows for repeated and noninvasive assessment of cytosolic phosphorus-containing compounds involved in energy metabolism (adenosine triphosphate ATP and inorganic phosphate Pi) and membrane phospholipids metabolism (phosphomonesters PME and phosphodiesters PDE)[1] in the liver. However, the quality of the acquired spectra may be degraded due to respiratory motion. In addition, when measuring a volume in the left lobe of the liver in e.g. patients undergoing partial hepatectomy, respiratory motion may cause contamination from surrounding tissues such as cardiac muscle. Retrospective motion correction based on navigator echo acquisitions has been shown to improve spectral quality in proton MRS of the liver[2]. The navigator correction technique furthermore allows for prospective volume tracking which was shown to improve signal-to-noise ratio (SNR) and fitting accuracy in cardiac ^{31}P MRS[3]. The objective of this work was to implement respiratory motion compensation for single voxel ^{31}P MRS in the liver including cardiac vector-ECG and respiratory navigator double triggering with navigator volume tracking.

Methods:

The measurements were performed on a 1.5T Intera whole body MR system (Philips Medical Systems, Best, The Netherlands) equipped with a multi-nuclei channel. A 10-cm single loop transmit/receive surface coil was positioned over the left lobe of the liver using MR imaging guidance. Typically, a volume of 30 x 40 x 70 mm^3 (84 ml) was selected with ISIS[4]. Cardiac triggering with a trigger delay of 600 ms after the R-wave was applied to prevent contamination from cardiac tissue as eight consecutive phase cycles are required for ISIS volume selection. Data were acquired with the following parameters: 512 data points, 1500 Hz bandwidth, repetition time at least 10 s, 96 signal averages. Neither proton-decoupling nor nuclear Overhauser enhancement was applied.

The navigator echo acquisition was implemented into the multi-nuclei spectroscopy software previously[3]. Prior to the acquisition a navigator preparation phase was performed to find the end-expiration position of the diaphragm. Iterative linear shim calibration was triggered to both the R-wave and the respiratory cycle (double-triggering). Only respiratory displacements within the gating window of 5 mm around end-expiration were accepted. The spectral acquisition was double-triggered after a minimal repetition time of 10 s. In addition to the double-triggering the excited volume was shifted by the determined respiratory displacement within the defined gating window in real-time (volume tracking).

Five healthy male volunteers were measured with three different acquisition schemes: A standard acquisition without navigator motion correction ("no correction"), an acquisition using a BISTRO[5] type chest wall saturation pulse ("saturation"), and an acquisition including the saturation and the navigator motion correction ("navigator"). An additional volunteer was measured at four different occasions using the navigator acquisition scheme only.

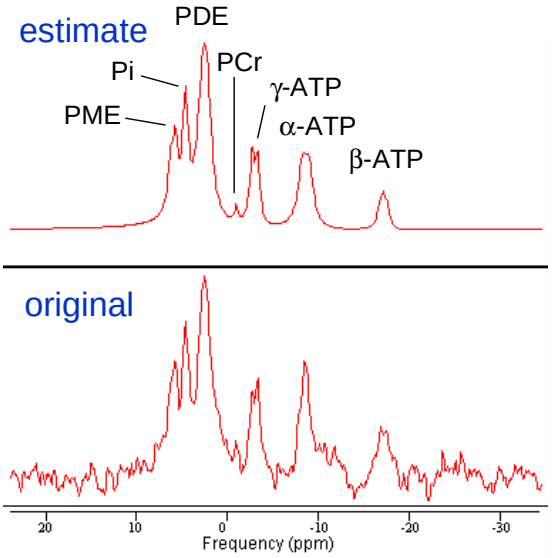

Figure 1: ^{31}P spectra from the left lobe of the liver acquired with the ecg and navigator double triggering. The estimate of signal components is shown along with the acquired spectrum.

The spectra quantification was performed using prior knowledge as proposed by Hamilton et al.[6] in the time domain using the AMARES algorithm included in the jMRUI software program[7]. Metabolite values are given as ratio of total visible phosphate.

Results:

Figure 1 shows an exemplary spectrum acquired in the left lobe of a healthy volunteer's liver using the proposed motion correction method. Fitting errors decreased by 44% and 53% compared to the acquisition without correction and with saturation only, respectively (Table 1). Contamination from phosphocreatine (PCr) was 3% of total visible phosphate on average for the "navigator" acquisitions in five volunteers. SNR of total visible phosphate was reduced by 15% and 5% for the "navigator" acquisition compared to the "no correction" and the "saturation" acquisition, respectively. High repeatability was achieved with the "navigator" acquisition in one volunteer measured at four different occasions (Table 2).

Discussion:

It has been demonstrated that respiratory motion correction based on navigator echoes increases the fitting accuracy in prior knowledge based quantification of ^{31}P liver spectra by about a factor of two. The decrease in SNR maybe due to increased suppression of signal contamination from outside the selected volume.

scheme	ATP	PCr	Pi	PDE	PME	average
navigator	1.00	1.00	1.00	1.00	1.00	1.00
saturation	0.99	2.19	0.91	2.25	3.22	2.11
no correction	1.07	1.21	1.07	1.94	2.60	1.81

Table 1: The cramer rao errors of the fit for the three different acquisitions. Values are normalized to one for the values of the navigator acquisition.

ATP	PCr	Pi	PDE	PME
.13±.02	.03±.02	.15±.03	.51±.07	.18±.03

Table 2: Repeatability measured with four acquisitions in one volunteer. Metabolite values are the ratio of total visible phosphate.

References:

[1] Ackermann, J. et al. Nature **283**, 1980
[2] Tyszka, J.M. et al. Magn. Reson. Med. **39**, 1998
[3] Kozerke, S. et al. Magn. Reson. Med. **48**, 2002
[4] Ordidge, R.J. et al. J. Magn. Reson. **66**, 1986
[5] Luo, Y. et al. Magn. Reson. Med. **45**, 2001
[6] Hamilton, G. et al. NMR Biomed. **16**, 2003
[7] Naressi, A. et al. Magma **12**, 2001