Evaluation of PCr/ATP ratio in the human heart at 7T using adiabatic excitation

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Introduction:

Phosphorus MR spectroscopy (^{31}P-MRS) provides a unique tool for the assessment of cardiac energy metabolism. The PCr/ATP concentration ratio in the heart changes in most disease states and can predict mortality[1,2]. Surface coils are typically used for 31P-MRS, but they cause inhomogeneous excitation across the myocardium, particularly at ultra-high fields. This makes metabolite quantitation challenging.

Therefore, our aim was to test the feasibility of adiabatic excitation for cardiac ^{31}P-MR 3D chemical shift imaging (CSI) at 7T.

Materials and Methods:

Measurements were performed on a 7T MR system (Siemens) using a Tx/Rx RF-coil[3], comprising a quadrature ^{31}P-coil (two 15cm loops) and a single 10cm ^{1}H-loop.

An adiabatic half passage (AHP) excitation pulse was adjusted for low adiabatic threshold and minimal SAR while preserving sufficient bandwidth (BW) to excite PCr and γ-ATP. Acquisition of 2,3-DPG, necessary for "blood correction"[4], was achieved by adapting the ultra-short echo time (UTE) 3D-CSI[5] sequence to support interleaved excitation of 2,3-DPG in even transients, and PCr and γ-ATP in odd transients.

Nine volunteers (7M/2F) were recruited, in compliance with local regulations. To test the interleaved AHP excitation in vivo, two 3D-UTE-CSI scans with different transmit voltages were acquired in each volunteer. Because of SAR restrictions, relatively long TR (3000ms) was mandatory. Therefore, to keep the acquisition time below 50min, and maintain minimal skeletal muscle contamination, a matrix size of 8x16x8 (RLxAPxHF) with a FOV of 240x240x200mm^3 was used.

For each subject, three septal voxels in two short-axis slices (six in total) were analysed. PCr, γ-ATP and 2,3-DPG signals were fitted using a Matlab implementation of AMARES[6] and corrected for partial saturation[7].

Results:

Figure 1 shows spectra acquired in skeletal muscle, liver and heart. Figure 2 shows a typical blood-corrected PCr/ATP map. The mean coefficient of variation of the PCr/ATP ratio across the evaluated septal voxels was 18.75% ± 4.94% ranging from 12.61% to 25.87%. The cardiac blood-corrected PCr/ATP ratios determined for every volunteer from each UTE-CSI acquisition are given in Table 1.

Discussion/Conclusion:

Our proof-of-concept study demonstrates that adiabatic excitation across the heart septum can be achieved in vivo at 7T. We have employed an AHP pulse in an interleaved excitation scheme into 3D-UTE-CSI sequence for uniform acquisition of blood-corrected PCr/ATP ratio. The use of a novel quadrature pair RF-coil increased available peak B_1^+, and thus, supported the feasibility of adiabatic excitation at 7T. This work paves the way for the first human studies with absolute quantification of cardiac ^{31}P metabolites at 7T.

References:

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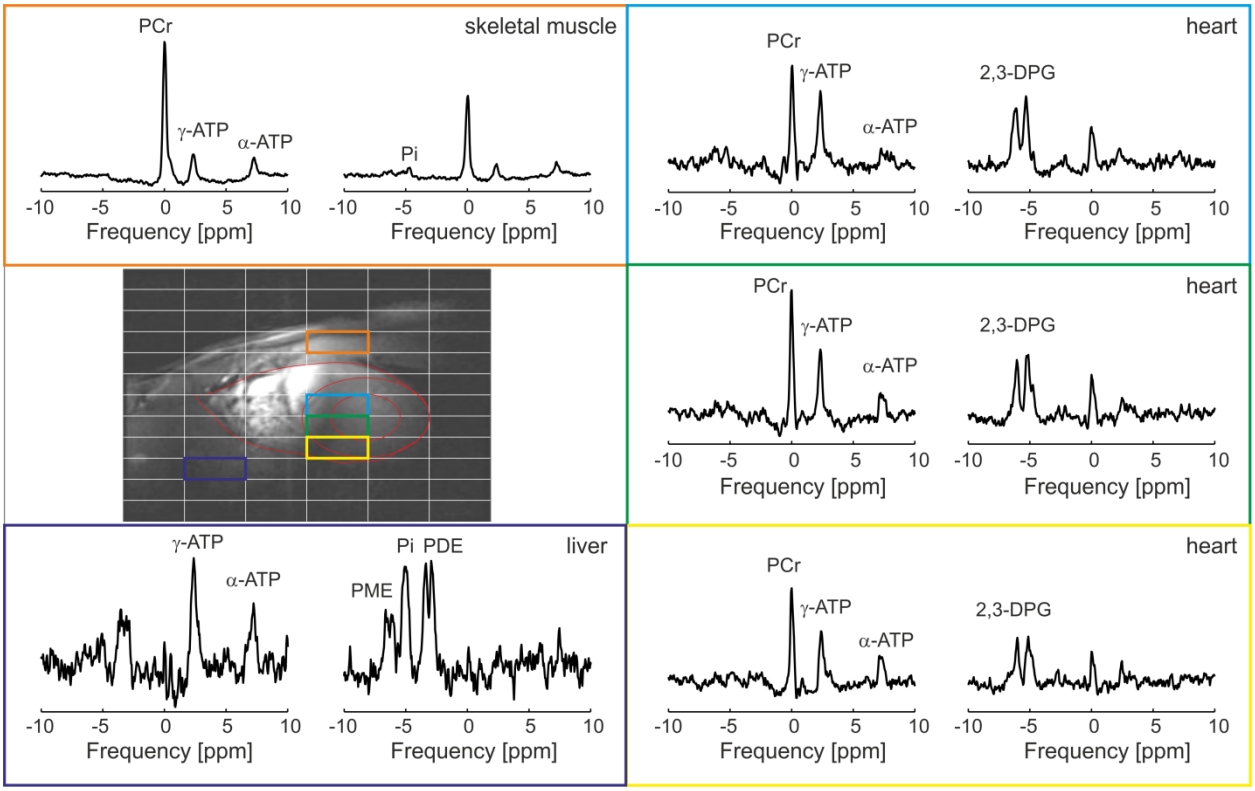

Figure 1: Typical acquired spectra from skeletal muscle, liver and from three of the selected voxels from the heart septum. A short axis 7T CINE FLASH localizer image showing the position of the selected voxels is also depicted. The spectra from the odd acquisitions are on the left, while on the right are depicted the spectra from the even acquisitions.

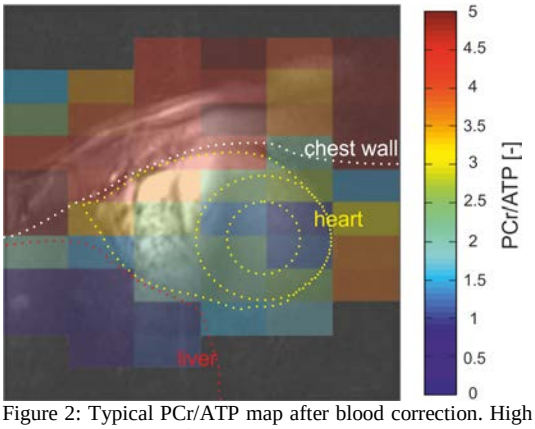

Figure 2: Typical PCr/ATP map after blood correction. High consistency across the heart throughout the sensitive volume of the coil is shown. Chest muscles exhibit significantly higher PCr/ATP ratio and the liver tissue shows zero PCr/ATP ratios as expected.

	PCr/ATP		
Subject	**MaxV**	**MaxV-50V**	**Mean**
1	1.96±0.29	1.94±0.43	1.95±0.35
2	2.01±0.37	1.85±0.47	1.93±0.38
3	1.93±0.37	2.08±0.38	2.00±0.30
4	2.27±0.28	2.23±0.58	2.25±0.39
5	2.14±0.52	2.13±0.64	2.13±0.55
6	2.02±0.45	2.20±0.55	2.11±0.47
7	2.19±0.27	2.11±0.35	2.15±0.27
8	2.47±0.59	2.38±0.66	2.42±0.61
9	2.22±0.29	2.33±0.31	2.28±0.29
Mean	**2.13±0.17**	**2.14±0.17**	**2.14±0.16**

Table 1: Mean blood corrected PCr/ATP ratios of each volunteer measured by interleaved UTE-CSI sequence using two different transmit voltages. Values are given as mean (±STD) of the six selected voxels of the heart for each individual subject and as mean (±STD) of the volunteers for the mean value