Comparison of Cardiac Phosphorous Spectroscopy at 1.5T and 3T

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Introduction: ^{31}P cardiac spectroscopy is inherently SNR limited because of the low metabolite concentrations (~10mM) and low gyromagnetic ratio. The emergence of clinical 3T scanners could yield the SNR increase that is needed to permit ^{31}P cardiac spectroscopy with a higher spatial resolution, enabling detection of regional metabolite variations, or with a higher temporal resolution, enabling measurement of dynamic changes in metabolite levels. In this work, we have systematically compared the achievable SNR of ^{31}P cardiac spectra between 1.5T and 3T

Methods: Spectra were obtained on a 1.5T (Siemens Sonata) and a 3T (Siemens Trio) clinical system using an ECG-gated, chemical shift imaging (CSI) protocol. The RF coils were geometrically identical with the 3T coil consisting of a standard Siemens 1.5T 31P coil that was modified for use at the higher field strength, this coil is composed of a large transmit element, and quadrature loop and butterfly receive elements. Nuclear Overhauser Enhancement was not used in this comparison, although the coils and MR system do support this.

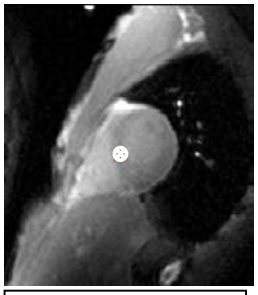

Figure 1: Typical Voxel Selection

^{31}P cardiac spectra were acquired in ten normal healthy subjects (5m, 5f) each being examined twice on each of the two scanners. All spectra were acquired with the volunteer in the prone position. After localization using conventional proton images, a 3D-CSI sequence was used with voxel dimension of 20x25x25mm, 1024 datapoints at 4kHz bandwidth (512 datapoints at 2kHz for 1.5T), TR of 1 R-R interval, flip angle hardcoded at approximately 45°, acquisition weighting[1] was used with 32 averages in the centre of k-space, and the total acquisition time was 1340 heart-beats (~20minutes).

A voxel was chosen at the centre of the anterior-posterior axis of the cardiac septum (fig. 1) and the resulting spectra were processed in jMRUI, using the AMARES algorithm[2] to fit for PCr, ATP, PDE and 2,3-DPG. Signal amplitudes were corrected based on literature values of the metabolite T_1s[3] and the calculated flip angle. SNR was quantified as the sum of the corrected signal amplitudes from the fit divided by the standard deviation of the residue.

Mean±SE	**1.5T**	**3T**	
SNR	107±6	240±30	p<0.001
PCr/ATP	2.0±0.2	2.1±0.3	p=0.9
TR (s)	1.04±0.04	1.03±0.04	p=0.9
Flip Angle (°)	43.5±0.6	52±2	P<0.001

* Paired t-Test - statistically significant (p<.05)

Results: High quality spectra were obtained in all volunteers and at both field strengths. Quantitative values are summarized in the table above. A significant increase (~100%) in SNR was seen at 3T compared with 1.5T. The local flip angle was also significantly greater at 3T, and more variable due to coil loading effects. Figure 2 shows typical spectra obtained at 1.5T (A) and 3T (B).

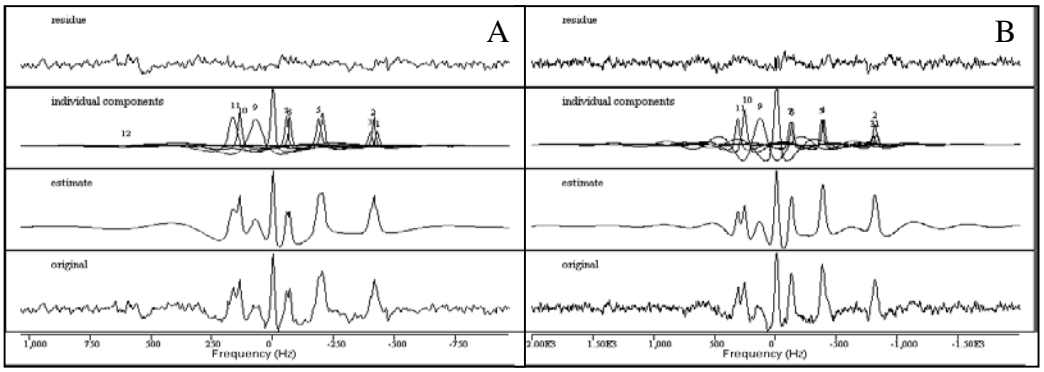

Figure 2: Typical Spectra from 1.5T (A) and 3T (B) Scans

Discussion & Conclusion: ^{31}P acquisitions at 3T show a significant SNR increase over 1.5T scans. This increase could be used to increase spatial resolution, minimizing spectral contamination from blood and skeletal muscle and providing the opportunity to investigate regional metabolite variations. Alternatively, the increased SNR could be used to increase temporal resolution, allowing the investigation of dynamic changes in metabolite levels.

The increase in SNR of cardiac ^{31}P spectroscopy appears to be consistent with the simplistic theoretical 100% increase when going from 1.5T to 3T. This doubling of SNR is not generally seen in proton acquisitions at 1.5T and 3T. The increase for ^{31}P is explained as being due to the similar T_1's of the phosphorus metabolites at the two field strengths, and to the relatively low frequency of ^{31}P, even at 3T.

References:

1 Beer M, et al. Journal of Magnetic Resonance Imaging 20:798-802 (2004)
2 Vanhamme L, et al. Journal of Magnetic Resonance 129:35-40 (1997)
3 Bottomley PA, et al. Magnetic Resonance in Medicine 32:137-141 (1994)