Journal of Cardiovascular Magnetic Resonance

Poster presentation

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Development and validation of a short 31P cardiac magnetic resonance spectroscopy protocol

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from 13th Annual SCMR Scientific Sessions
Phoenix, AZ, USA. 21-24 January 2010

Published: 21 January 2010

Journal of Cardiovascular Magnetic Resonance 2010, **12**(Suppl 1):P123 doi:10.1186/1532-429X-12-S1-P123

This abstract is available from: http://jcmr-online.com/content/12/S1/P123

Introduction

Cardiac 31P-MRS is the only non-invasive in vivo technique for the determination of cardiac high energy phosphate metabolism. Changes in cardiac phosphocreatine to adenosine triphosphate ratios (PCr/ATP) occur in common cardiac pathologies and have diagnostic, prognostic and therapeutic utility. However, long acquisition times (20 minutes or more, depending on heart rate) required to achieve sufficient signal to noise ratios for reliable interpretation have limited the clinical utility of 31P-MRS studies in patients with severe cardiac disease.

We have developed an 8 minute 31P-MRS protocol and demonstrate the validity of this 'short' acquisition by comparison with a 'long' (at least 20 minutes) method of published reproducibility (Tyler, NMR Biomed:2008).

Purpose

To design a robust, 'short' cardiac 31P-magnetic resonance spectroscopy (31P- MRS) protocol which facilitates acquisition within a clinically acceptable timeframe.

Methods

Protocol development

This 'short' protocol essentially incorporates a larger voxel (93 mls compared to 39 mls for 'long' protocol) but eliminates extra myocardial contamination by:

• active suppression of chest wall muscle and liver signals,

• raw data acquisition weighted to reduce contamination arising from outside the nominal voxel.

The accuracy of the data and its interpretation is improved by:

• optimised radio frequency (RF) pulse,

• flip angle calibration (at voxel of interest) used during post-processing to calculate and correct for subject variation to coil loading.

• calibrated signal enhancement (Nuclear Overhauser Enhancement (NOE)),

• rapid repetition time (with calibrated saturation correction).

Validity

22 healthy volunteers (age 42 ± 16.5; 13 males, 9 females), were scanned (3 T Siemens Trio) with both the 'long' and 'short' acquisitions.

Acquisition parameters for both protocols are summarised and compared in Table 1.

Table 1: Selected acquisition properties of compred protocols

	Control (long, 20 min) protocol	Short (8 min) protocol
3D CSI Matric size	16 × 16 × 16	16 × 8 × 8
Field of view	240 × 240 × 240 mm	240 × 240 × 240 mm
Voxel size	29 mls	93 mls
Cardiac gated	Yes	No, TR 720 ms
Acquisition time	>+ = 20 mins	8 min
Chest wall muscle saturation	Yes	Yes
Liver saturation	No	Yes
NOE	Yes	Yes
RF saturation, NOE and blood correction factors applied	Yes	Yes
Subject specific flip angle map acquired	Yes	Yes

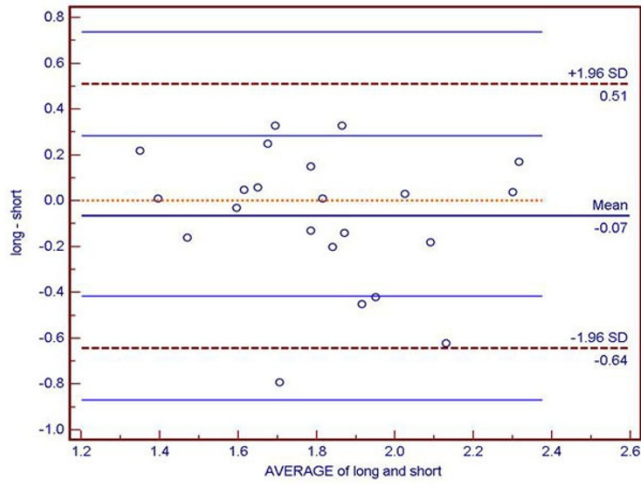

Figure 1
PCr/ATP ration derived from data acquired with the 'long' versus the 'short' 31P-MRS methods using a Bland Altman plot.

Results

There was no difference of derived PCr/ATP ratios for both methods ('short' 1.83 ± 0.32; 'long' 1.78 ± 0.27). Bland-Altman analysis demonstrates excellent agreement between the two methods (Figure 1) confirming equivalence for clinical purposes. Figure 2 shows an example of spectra acquired from one subject, using both methods.

Conclusion

We have developed a novel 'short' cardiac 31P-MRS protocol of high data quality. This protocol allows cardiac spectroscopy to be measured in patients who are often intolerant of long acquisition times, such as those with severe cardiac disease and children. Hence this work provides a useful tool for the routine clinical assessment of cardiac 31P-MRS.

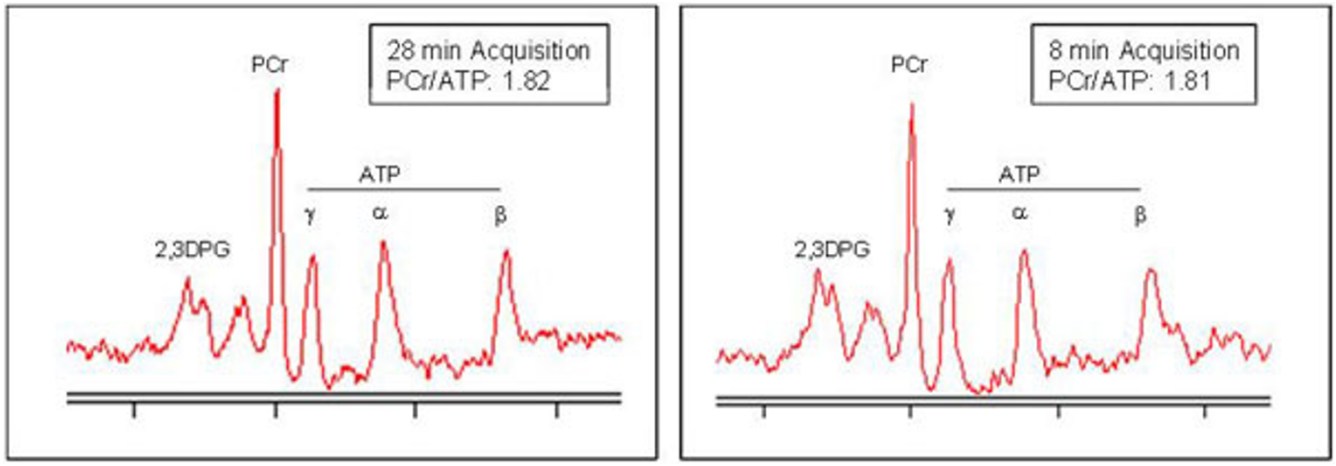

Figure 2
Comparing spectroscopy for one subject (heart rate 60), requiring 28 minutes for the 'long' control acquisition vs the new 'short' (8 minute) protocal. PCr (phosphocreatine); 2, 3 DPG (2, 3 diphosphoglycerate); ATP (adenosinetriphosphate) are indicated.