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Cardiac metabolism with hyperpolarized [1-^{13}c]pyruvate: a feasibility study in mini-pig with a large dose injection

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Introduction

MRI with hyperpolarised ^{13}C represents a promising modality for *in vivo* spectroscopy and it could provide a unique opportunity for non invasive assessment of cardiac regional metabolism.

Purpose

The aim of this work is to study real time *in vivo* cardiac metabolism after intravenous (i.v.) injection of hyperpolarized [1^{13}C]-pyruvate in a large animal model with a clinical 3T scanner.

Methods

Animal model

Four normal male mini-pigs (35 kg) were maintained under deep sedation with midazolam (0.1 mg/kg/h i.v.) while ECG, temperature and arterial blood pressure were monitored (SA Instruments, New York USA).

Polarization

^{13}C-1-pyruvate Hyperpolarization was performed using Dynamic Nuclear Polarization (*Hypersense*, Oxford Instruments, Oxford, UK). The final injection solution contained 230 mM sodium [1-^{13}C]pyruvate, 100 mM TRIS buffer, 0.27 mM Na_2EDTA and 20 microM Dotarem (Guerbet, Paris, France). Temperature of solution was about 37°C and pH = 7.6. A dose of 20 mL was administered over 10 s by manual injection.

MR studies

The mini-pigs underwent both ^{1}H MR imaging and hyperpolarized ^{13}C MRS. The experiments were performed with a 3 T GE Signa HDx (GE Healthcare, Waukesha, WI, USA) scanner with a 13C quadrature birdcage coil (Rapid Biomedical, Würzburg, Germany). Anatomical imaging was acquired with the body coil and FIESTA sequence (FOV=35, FA=45, TE/TR=1.71ms/3.849ms).

^{13}C dynamic spectra were acquired using elliptic-FIDCSI pulse sequence (bandwidth 5000Hz, 2048 pts, 10° FA). A long-axis slice of 20 mm was selected during excitation. Spectra covering the heart were acquired from the beginning of the injection of the hyperpolarized [1-^{13}C]pyruvate, every 2 s, for 120 s.

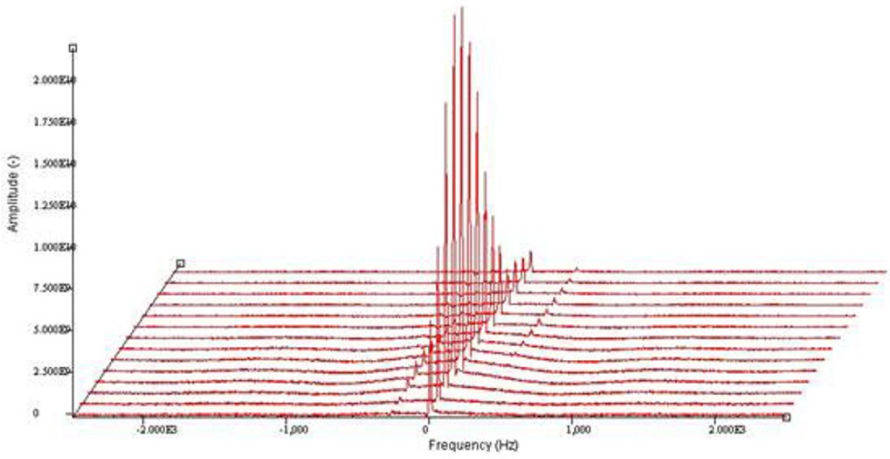

Figure 1

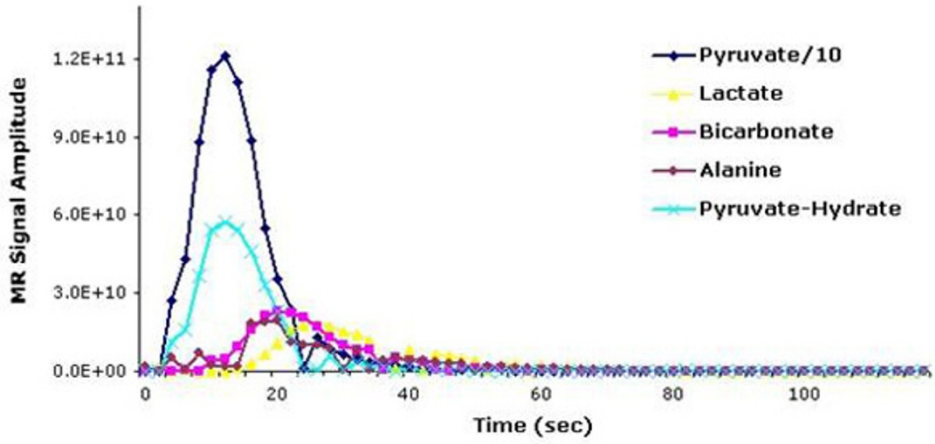

Figure 2

Data processing

Data processing was performed by using MATLAB (The Mathworks, Inc., Natick, MA) and jMRUI software tools. The dynamic spectra were phase corrected by adjusting both zero-and first-order frequency-dependent phase components. Pyruvate, pyruvate hydrate, alanine, lactate, and bicarbonate were estimated by using AMARES algorithm included into jMRUI tools. Accordingly, time courses of metabolites are generated.

Results and discussion

Spectra obtained from the dynamic acquisition are shown in Figure 1. The [1-^{13}C]pyruvate, [1-^{13}C]pyruvate hydrate and metabolites peaks ([1-^{13}C]lactate, [1-^{13}C]alanine, and ^{13}C-bicarbonate) have been detected and plotted. Figure 2 shows the *in vivo* time course of cardiac metabolites.

Conclusions

Imaging cardiac metabolism with hyperpolarized ^{13}C is feasible with 3T MRI in an animal model that closely resembles the human heart phenotype.