

MRI/MRS biomarkers for response evaluation in patients with CABG

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Background: phosphorus-31 magnetic resonance spectroscopy (³¹P-MRS) represents a unique instrument to noninvasively monitor myocardial metabolism in humans. The technique has been used to study the metabolism in myocardium in patients with coronary artery disease (CAD). The measurements permit quantitative estimation of the phosphocreatine (PCr)/adenosine triphosphate (β -ATP) ratio which reflects the energetic state of the myocardium. Previous studies have investigated the effect of successful coronary artery bypass grafting surgery (CABG) upon left ventricular function. Although residual myocardial viability in patients with CAD and extensive regional asynergy is associated with improved ventricular function after CABG, the relationship between myocardial metabolism and heart function after CABG remains unclear. We hypothesized that cardiac function benefits from high-energy phosphate (HEP) and sought to investigate the relationship between HEP and cardiac function in CAD patients using cine magnetic resonance imaging (cine-MRI) and ³¹P-MRS. **Materials and Methods:** Thirteen patients (age 56 ± 4.8 years) with both anterior wall motion abnormality of the left ventricle and ischemic myocardium were included in the retrospective study. Left ventricular ejection fraction (LVEF) was evaluated using cine-MRI. HEP such as PCr and β -ATP within the anterior wall myocardium was measured using ³¹P-MRS to calculate PCr/ β -ATP ratio. Cine-MRI and ³¹P-MRS measurements were performed before and after CABG, respectively. Ten normal healthy volunteers served as control group. Magnetic resonance measurements were conducted using a 1.5T whole-body MR instrument (Magnetom Vision; Siemens, Erlangen, Germany). All studies were performed in supine position, using a phased-array cardiac coil. A short-axis cine MRI scan was performed using two-dimensional (2D) bright blood gradient echo sequence (GRE) with following parameters: slice thickness 8 mm, TR between 8.0 ~ 8.5 ms, TE between 1.5 ~ 4.8 ms, flip angle was 20°, matrix 256 × 128, and 8 slices were acquired. Field of view varied by patients, with a range between 350 and 450 mm. Following MRI examination, 2D chemical shift imaging (CSI) ³¹P-MRS was performed with FOV 320 × 320 mm, flip angle 90°, TE 3 ms, and 30 mm axial slice-selective excitation was used. ³¹P-MRS procedure was phase encoded in arrays of 8 × 8 steps with an average of five acquisitions. K-space zero-filling was used, yielding $2 \times 2 \times 3$ cm³ volume elements (voxel). TR was set to one R-R interval for the 2D-CSI measurement. The ³¹P-MRS acquisition time was 5-6 min. The total examination time of the ³¹P-MRS procedure was 25~30 min, depending on the heart rate (Figure 1). **Results:** ³¹P-MRS in 13 patients showed significant changes in PCr/ β -ATP ratio after CABG had significant differences compared with that of normal myocardium of healthy volunteers (pre-CABG vs. control, 1.43 ± 0.24 vs. 2.13 ± 0.21 ; post-CABG vs. control, 1.71 ± 0.29 vs. 2.13 ± 0.21 , $p < 0.05$, respectively). PCr/ β -ATP ratio following CABG was significantly higher than that before CABG ($p < 0.05$) (Figure 2). With the change of the ratio, the left ventricle function was significantly improved (LVEF changed from 35.7 ± 12.9 pre-CABG to 45.6 ± 17.2 post-CABG, $p < 0.05$). **Conclusions:** ³¹P-MRS and cine-MRI biomarkers can be used to noninvasively evaluate the myocardial bioenergetics, morphology and function after revascularization in patients with CAD. Cardiac function clearly improves during detection of increased HEP recovery. The ability to non-invasively assess changes of metabolism in myocardium may prove important for patient-specific optimization of treatment strategies.

Figure 1

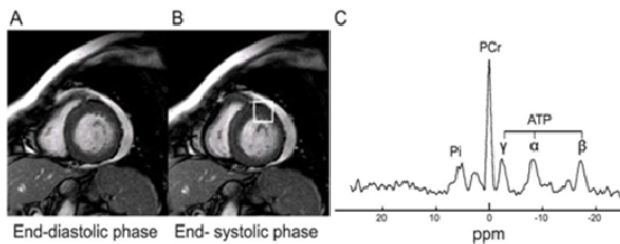


Figure 1. Short-axis cine-MRI and 2D-CSI ³¹P-MRS of a 65-year-old male patient before CABG. A: end-diastolic phase and B: end-systolic phase, LVEF = 36.2%. C: typical ³¹P-MR spectrum acquired from the LV anterior wall myocardium (white squares) for the patient, PCr/ β -ATP = 1.23.

Figure 2

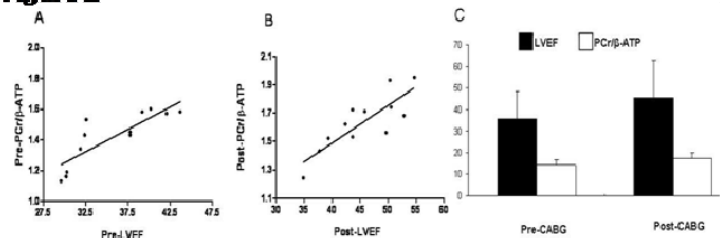


Figure 2. The correlation between the LVEF and the PCr/ β -ATP ratio. A: before CABG, there was a significant correlation ($R^2 = 0.71$, $p < 0.05$) between LVEF and PCr/ β -ATP ratio. B: the significant correlation was shown after CABG, $R^2 = 0.71$, $p < 0.05$. C: a significant difference was found after CABG for LVEF and PCr/ β -ATP ratio ($p < 0.05$, respectively).