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Three-dimensional magnetic resonance mapping of cardiac metabolism by hyperpolarized 13C-pyruvate in a pig model of ischemia-reperfusion

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The objective of this study was to evaluate the capability and accuracy of MRI with hyperpolarized [1-13C] –pyruvate with using the fast three-dimensional pulse sequence to detect the presence and the regional distribution of transient cardiac metabolic changes in a pig model of ischemia/reperfusion. In 7 male pigs a pneumatic coronary occluder was placed around the left anterior descending coronary. [1-13C]pyruvate polarization was performed using DNP as previously described (1). Injections were performed at rest, during coronary occlusion, and during reperfusion. A 3D-IDEAL spiral sequence was used at 3T MRI scanner (2). Metabolite signal was evaluated in 120 myocardial sectors. The Metabolic Activity Mismatch (MAM) between two segmental variation maps was defined as $100(S_{ai}-S_{bi})/(S_{ai}+S_{bi})/2$, where S_{ai} and S_{bi} are the relative values of the signal of metabolite in the segment "i" in condition "a" and "b".

The MAM of lactate and bicarbonate of the ischemic segments (middle and apical anteroseptal and anterior segments) were significantly different from the remote regions. In reperfusion a significant inhomogeneity of MAM of bicarbonate ($P<0.001$) was found, whereas, no significant difference was found for lactate. Figure 2 shows a different distribution for either lactate (−21±6 vs 3±5, $P<0.001$) or bicarbonate metabolic activity (−29±7 vs 33±6, $P<0.0001$) in LV segments involved by ischemic process than in remote

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Conflict of Interest:
None.

segments. In reperfusion, lactate signal increased (*20±10 vs −7±5, P= 0.007)* and bicarbonate decreased (*−38±12 vs 36±11, P<0.0001*) in involved segments.

We evaluated cardiac metabolism in vivo during ischemia and acute reperfusion with a whole heart acquisition using volume coils and with high spatial resolution acquisition. Neither of these requirements was met by previously described methods. The main finding of the current study was the demonstration that spatial resolution obtained using a 3D-IDEAL Spiral CSI pulse sequence was high enough to provide three-dimensional information of acute changes of pyruvate and metabolites in left ventricular myocardium using the conventional regional segmentation.

The IDEAL spiral CSI pulse sequence permits to get the complete 3D-dataset of information, with optimal signal to noise ratio and with short acquisition time, for each metabolites simultaneously. This might be potentially relevant for the application of hyperpolarized [1-13C]-pyruvate in human allowing complete acquisition during one breath-hold, increasing the SNR and minimizing the effect of the main limitation of this technique which the fast signal decay of hyperpolarized substrates.

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References

1. Menichetti L, Frijia F, Flori A, Wiesinger F, Lionetti V, Giovannetti G, Aquaro GD, Recchia FA, Ardenkjaer-Larsen JH, Santarelli MF, Lombardi M. Assessment of real-time myocardial uptake and enzymatic conversion of hyperpolarized [1-13C]pyruvate in pigs using slice selective magnetic resonance spectroscopy. Contrast Media & Molecular Imaging. 2012; 7:85, 94. [PubMed: 22344884]
2. Wiesinger F, Weidl E, Menzel MI, Janich MA, Khegai O, Glaser SJ, Haase A, Schwaiger M, Schulte RF. IDEAL spiral CSI for dynamic metabolic MR imaging of hyperpolarized [1-(13) C]pyruvate. Magn Reson Med. 2011 Epub ahead of print. 10.1002/mrm.23212

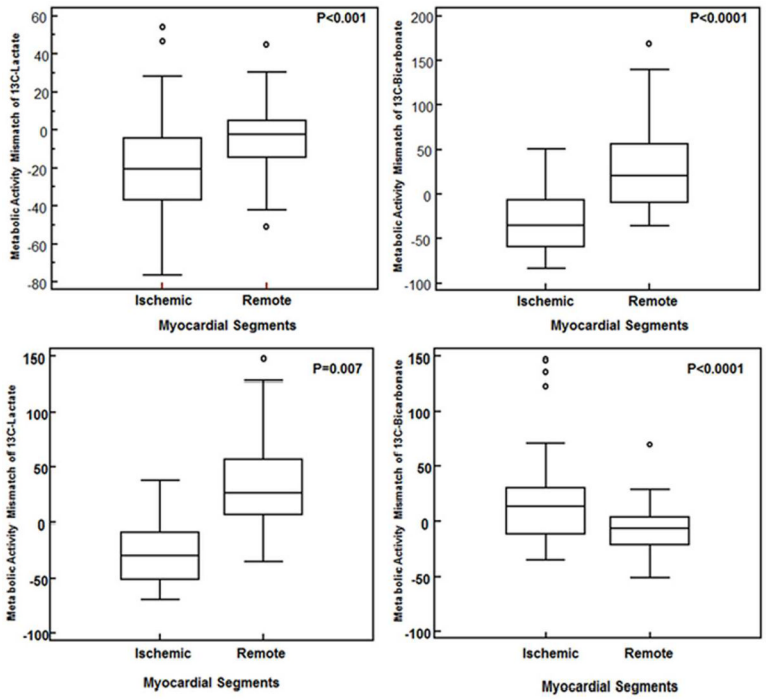

Figure 1.
Box-and-Whiskers plots showed during occlusion (upper panels) and reperfusion (lower panels).