Apparent rate constant mapping using hyperpolarized \([1-(13)C]\)pyruvate.

Abstract:
Hyperpolarization of \([1-13C]\)pyruvate in solution allows real-time measurement of uptake and metabolism using MR spectroscopic methods. After injection and perfusion, pyruvate is taken up by the cells and enzymatically metabolized into downstream metabolites such as lactate, alanine, and bicarbonate. In this work, we present comprehensive methods for the quantification and interpretation of hyperpolarized \(13C\) metabolite signals. First, a time-domain spectral fitting method is described for the decomposition of FID signals into their metabolic constituents. For this purpose, the required chemical shift frequencies are automatically estimated using a matching pursuit algorithm. Second, a time-discretized formulation of the two-site exchange kinetic model is used to quantify metabolite signal dynamics by two characteristic rate constants in the form of (i) an apparent build-up rate (quantifying the build-up of downstream metabolites from the pyruvate substrate) and (ii) an effective decay rate (summarizing signal depletion due to repetitive excitation, T1-relaxation and backward conversion). The presented spectral and kinetic quantification were experimentally verified in vitro and in vivo using hyperpolarized \([1-13C]\)pyruvate. Using temporally resolved IDEAL spiral CSI, spatially resolved apparent rate constant maps are also extracted. In comparison to single metabolite images, apparent
build-up rate constant maps provide improved contrast by emphasizing metabolically active tissues (e.g. tumors) and suppression of high perfusion regions with low conversion (e.g. blood vessels). Apparent build-up rate constant mapping provides a novel quantitative image contrast for the characterization of metabolic activity. Its possible implementation as a quantitative standard will be subject to further studies.