Refocused Acquisition of Chemical Exchange Transferred Excitation: Use of Phase in Exchange MRI

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Introduction: In 2018 we demonstrated RACETE[1] as an alternative to the CEST-approach for visualizing chemical exchange. Like CEST, RACETE can improve sensitivity by repeated transfer of magnetization. However unlike CEST, RACETE refocuses transferred excitation by exploiting the stimulated echo (STE) pathway, enabling a multitude of new possibilities[2] two of which are presented here.

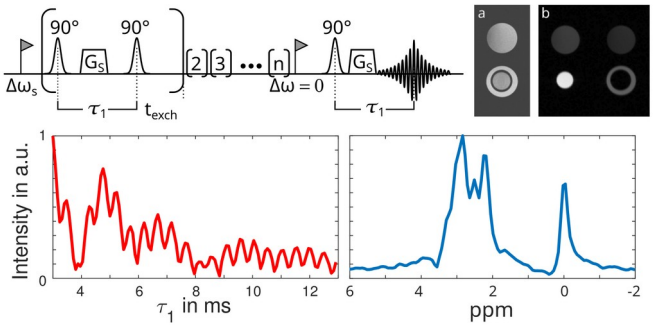

Figure 1: Top left: Sequence diagram, Top right: Phantom, a) TSE-Image b) RACETE image with separation of substances. Bottom: Absolute signal and corresponding spectrum using frequency labeled exchange.

In Fig. 1a the basic RACETE sequence diagram is shown. Two frequency-selective pulses are used to prepare an STE. During the first time interval (τ_1), a chemical shift-dependent phase is accumulated and an encoding encoding gradient (G_S) is applied. In the subsequent interval, all relevant magnetization is stored along the longitudinal axis, so no further phase is accumulated. This leads to a well-defined phase of the resulting stimulated echo, which can be read out on the water frequency after repeated excitation.

Methods/Results: Multi-substance RACETE using k-space dependent phase offsets: The phase of the RACETE signal can be controlled via the phase difference of the excitation pulse pair. By using a dual-band excitation, two pools can be excited simultaneously. Manipulating the excitation phase of one of the pools across phase steps allows shifting the corresponding image for one of the substances arbitrarily. This enables the separation of the simultaneously acquired two pool experiment similarly to a POMP experiment[3].

A vial containing salicylic acid (50 mmol/L) containing a smaller vial of Iomeprol solution (80 mmol/L) and another vial containing a mixture of both were imaged using a 17.5 T system. Fig.1a shows a spin-echo image, and Fig.1b presents the RACETE contrast with clear separation achieved using the approach described above.

Methods/Results: Measurement of exchange Spectra using frequency labeled exchange: When multiple substances with distinct chemical shifts are excited during preparation, each accumulates a unique phase during the τ_1-interval[4]. By varying this interval, a characteristic signal evolution is obtained. The resulting complex signal can then be directly transformed into a frequency spectrum representing the contributing exchanging species. In Fig 1. (bottom) both the signal and the corresponding spectrum of egg white (hen's egg), acquired on a 17.5 T system, are shown.

Conclusion: RACETE can generate true positive contrast chemical exchange contrast. The transfer of phase enables novel approaches for chemical exchange imaging.

References:[1] Gutjahr, ZMedPhys. (2019). [2] Zhao, MRI (2022). [3] Glover, JMR (1991). [4] Friedman, JACS (2010).