Simplified RF spillover-corrected omega plot for simultaneous determination of labile proton ratio and exchange rate
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Introduction CEST MRI provides an exchange-dependent contrast mechanism that is sensitive to dilute CEST agents and microenvironment properties, and remains promising for a host of in vivo applications. However, CEST MRI contrast is complex, depending on not only the labile proton concentration and exchange rate, but also on the experimental parameters such as the field strength and RF irradiation power. It has been shown that the CEST effect can be described as a multiplication of the simplistic CEST contrast, the labeling coefficient and the spillover factor. The labeling coefficient quantifies the saturation efficiency of the exchangeable protons, while the spillover factor calculates the direct RF saturation of the bulk water signal, which competes with the CEST effect. Because the RF spillover factor shows very little variation with labile proton ratio and exchange rate, we postulated that the RF spillover factor can be estimated and compensated so that both the labile proton ratio and exchange rate can be determined from the proposed simplified qCEST analysis.

Materials and Methods Phantom: Creatine solution was added to trace gadolinium-doped phosphate buffered solution (PBS) at concentrations of 20, 40, 60, 80 and 100 mM; pH was titrated to 6.75. MRI: Single-slice, single-shot echo planar imaging (EPI) images were obtained from a 4.7 T small-bore MRI scanner. For the CEST MRI, 3-point CEST imaging was performed with continuous wave (CW) RF irradiation applied at ±1.875 ppm, in addition to a control scan. The RF power was varied from 1, 1.5, 2, 2.5 and 3 µT (TR/TE = 12,000/28 ms, NSA=2) and T2 (TR=12,000 ms, NSA=2) were obtained using inversion recovery and spin echo MRI, respectively. All images were processed in Matlab.

Results and Discussion

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Fig. 1 evaluates the proposed qCEST analysis using simulated CEST results based on the RF irradiation amplitude, offset and relaxation constants, and the spillover factor-corrected CEST effect can be calculated as CESTR = CEST/(1 - α). Both the labile proton ratio and exchange rate can be determined from the linear regression fitting, being f = R0/w/(ksw*(C0-1)), and ksw=(sqrt(R0s^2+4C1)/(C0-1))-R0s/2, respectively.

Fig. 2 validates the proposed algorithm using a quantitative CEST MRI phantom. Specifically, Fig. 2a shows CEST MRI is sensitive to creatine concentration. Using the proposed simplified qCEST analysis, we found the exchange rate to be 149 ± 12 s^-1 (Fig. 2b), and its correlation with the creatine concentration was insignificant (p = 0.56, P = 0.32).

References