More phase information from a single CEST scan
: Simultaneous B_0, susceptibility- and CEST-weighted Imaging with rosette k-space trajectories

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INTRODUCTION: CEST-MRI, especially APT-weighted imaging is a powerful tool for assessing neurological diseases, such as brain tumors and ischemic stroke[1-3]. However, the complete information obtainable from CEST imaging is often not utilized, which can provide a deeper insight into the pathology. For instance, only magnitude images acquired from CEST experiments are typically used, but phase information is ignored. In a gradient echo-based CEST imaging sequence, the phase of the images contains important information, such as the B_0 inhomogeneity and susceptibility of *in vivo* tissues[4]. Herein, we demonstrated the feasibility of simultaneous APTw, susceptibility-weighted imaging (SWI), and B_0 mapping from a single image acquisition using motion-robust (oversampling in the center of k-space) rosette k-space trajectories.

METHODS: The rosette-CEST sequence consisting of an RF saturation preparation followed by rosette GRE readout is shown in Fig. 1. The rosette k-space trajectory is given by: $k(t) = k_{max}\sin(\omega_1 t)e^{i\omega_2 t}$, where ω_1 and ω_2 are radial oscillation and in-plane rotation frequencies. A flow-compensated rosette readout was designed, where the 1st-order gradient moments in the x-y directions at TE were 0. A healthy volunteer was recruited. The study was approved by the IRB, and written consents were obtained from the subject before scanning. Six saturated images were acquired at ±3, ±3.5, ±4 ppm with an RF saturation duration of 2.1 s and strength of 2 μT, and an unsaturated image (S_0) was acquired for normalization. A slightly longer TE (15 ms) was used for the rosette readout to sensitize T_2* effect for SWI. Other acquisition parameters were: FOV = 256 x 256 mm^2, matrix size = 128 x 128, ω_1/ω_2 = 3500/4500 rad/s, number of shots = 75, flip angle = 10°, TR = 17 ms, slice thickness = 4 mm, and number of slices = 10. The phase of the rosette images generated from all the shots (φ_1 in Fig. 2) was used to create a phase mask following high-pass filtering and combined with the magnitude images to generate the SW images. Each rosette shot was divided into two halves to generate dual-echo images, and the phase difference of the dual-echo rosette images (φ_2 and φ_3 in Fig. 2) was used to generate the B_0 maps. Finally, the APTw images were generated from MTR asymmetry analysis at 3.5 ppm.

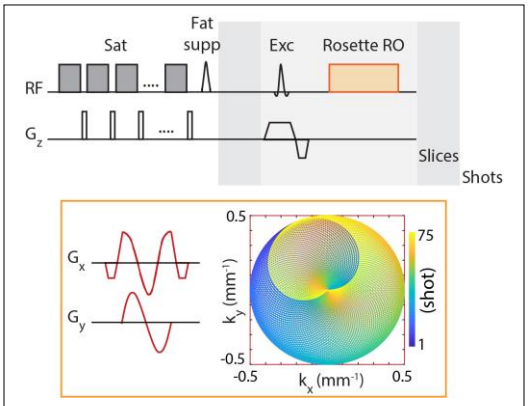

Figure 1: Schematic of the rosette-CEST sequence consisting of RF saturation preparation and rosette readout (RO).

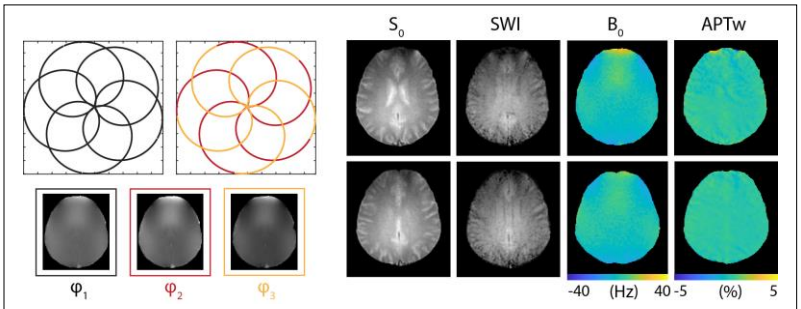

Figure 2: The phase of the rosette images reconstructed from all the shots (φ_1) was processed and combined with the magnitude images (S_0) to generate SWI. Here, only five rosette shots are shown for clarity. The phase of the dual-echo rosette images from two halves of each shot (φ_2 and φ_3) were used to estimate the B_0 maps. APTw images were generated using MTR asymmetry analysis at 3.5 ppm.

RESULTS: High-quality SWI was obtained from a single CEST scan, where susceptibility-dependent contrast was clearly visible (Fig. 2). The SWI highlighted areas with short T_2* and led to lower signal intensities in veins due to the presence of deoxyhemoglobin. Accurate B_0 maps were obtained from the dual-echo rosette images, which showed a high degree of accuracy with a conventional dual-echo GRE sequence (data not shown here). Reliable APTw images were also generated from the same acquisition, where there should be negligible APTw contrast between normal GM, WM, and CSF in a healthy volunteer for the settings used[5].

DISCUSSION: The total scan time (for 7 dynamic scans, 10 slices, 75 shots) was 1 min 45 sec. However, further optimization of the rosette readout could improve the imaging time (e.g., 44 sec for 25 shots) or make a whole brain coverage in an equivalent scan time (e.g., 1 min 45 sec for 30 slices, 25 shots).

CONCLUSION: This study demonstrates the feasibility of simultaneous B_0, APTw and SW imaging from a single acquisition using motion-robust rosette trajectories that can be rapidly translated to routine clinical use.

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