Theoretical and Experimental Investigation of Imaging 2D Interslice MT Ratio Asymmetry

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Introduction

In the absence of a dedicated preparation pulse, magnetization transfer (MT) effects commonly occur in multi-slice 2D imaging. These interslice MT effects may be exploited as new methods for imaging MT effects. Recently a new imaging technique, termed alternate ascending/descending directional navigation (ALADDIN), was developed for the acquisition of perfusion-weighted (PW) [1] and magnetization transfer (MT) asymmetry imaging [2], based on interslice blood flow and MT effects, respectively. The absence of a dedicated RF pulse for spin preparation differentiates ALADDIN MT asymmetry imaging from conventional techniques. Knowledge of MT asymmetry responses to variation of scan parameters is crucial for the optimization and validation of ALADDIN MT asymmetry imaging. In this study, we theoretically and experimentally investigated the effects of RF power (i.e., flip angle) on ALADDIN MT asymmetry images.

Material and Methods

All experiments were performed on a 3T whole body scanner (Siemens Medical Solutions, Erlangen, Germany) with body coil transmission and 12-element head matrix coil reception. ALADDIN PW imaging was performed on the brains of three healthy volunteers by acquiring four datasets from alternating ascending/descending acquisitions and positive/negative slice-select gradients using positive readout gradient followed by the same four data acquisitions using negative readout gradient (total 8 repetitions). Imaging parameters were TR/TE = 4.1/2.1 ms, matrix size = 128 × 128, FOV = 230 × 230 mm^2, thickness = 5 mm, gap = 7 mm, scan direction = axial, delay time between repetitions = 8−10 sec, and scan time per dataset = ~2.5 min. Datasets were acquired with both centric and linear PE orders at flip angles varying from 15° to 90° with 15° step. To map the MT ratio asymmetry (MTR_{Asym}) in the conventional unit (percent unit, p.u.), MT free images (M_0) were acquired with the positive slice-select gradient, ascending order, 8-s inter-slice delay time, and scan time of ~1 min. Datasets were reconstructed as both MTR_{Asym} and percent signal changes (PSC) between datasets of positive and negative MT frequencies [2]. ROI analysis was performed for a whole white matter region manually segmented from the center slice. Simulations of Bloch equations were performed to determine MT asymmetry of WM with T_1 and T_2 values of 1084 msec and 69 msec, respectively [3], based on a modified two-pool MT model [4].

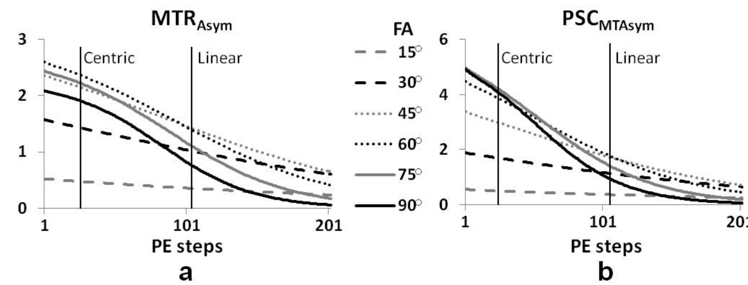

FIG. 1. Simulation results for MT ratio asymmetry (MTR_{Asym}) (**a**) and percent signal changes of MT asymmetry (PSC_{MTAsym}) (**b**) as a function of PE step at various flip angles.

Results and Discussion

According to the simulation, initial differences in longitudinal magnetizations between positive and negative MT frequencies was the highest at flip angle 60° and decayed with RF excitation faster at higher flip angle (Fig. 1). The experimental results are shown for one representative subject (Fig. 2a) and for all the subjects in comparison with the simulation results (Fig. 2b,c). Overall MTR asymmetry signals peaked at flip angle around 45°−60° (Fig. 2). The simulation results agreed well with the experimental results. Percent signal changes peaked at slightly higher flip angle (60°) than MTR asymmetry (45°) for centric PE order (Fig. 2b), presumably due to higher MT effects at higher flip angles (more signal reduction in the baseline images). Linear PE order peaked at lower flip angle than the centric PE order for PSC, due to the faster signal decay with RF excitations at higher flip angle (Fig. 1). For centric PE order, some flow-related artifacts were observed in MT asymmetry images at high flip angles (75°−90°) in some subjects (arrow in Fig. 2a). Overall centric PE order provided about twice higher MT asymmetry signals than linear PE order (Fig. 2).

There are similarities and differences between MTR asymmetry and MTR. The former represents the offset of center frequencies between the free water and bound pools and the latter is about the strength of the MT effects overall. Although the two images look similar in normal subjects, they may provide distinct information under pathologic conditions. Magnetization transfer ratio asymmetry may potentially advance to imaging of chemical information (pH-weighted CEST imaging) [5], whereas MTR is more likely about cellular metabolic information associated with macromolecules. The current study helps us to understand and optimize the interslice MT asymmetry signals and potentially to advance the technique to pH-weighted imaging [5].

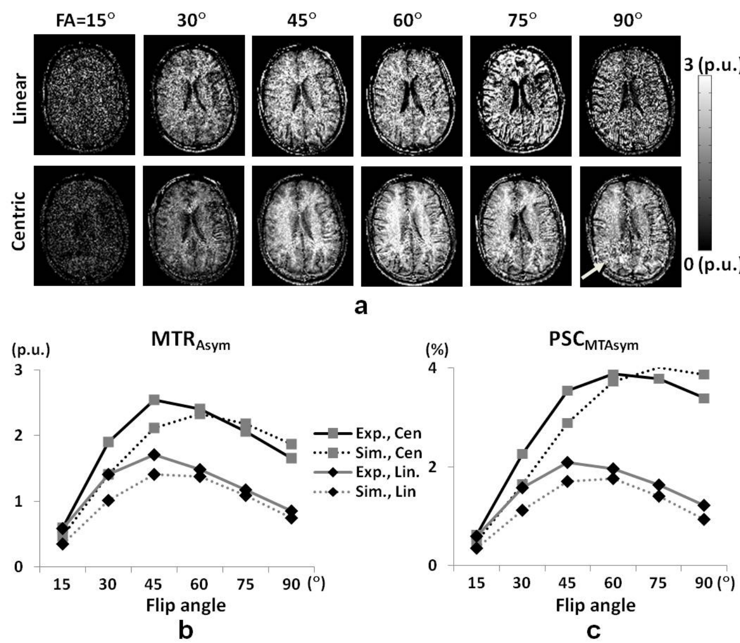

FIG. 2. Experimental results for magnetization transfer (MT) asymmetry signals. **a**: MT ratio asymmetry images (MTR_{Asym}) acquired with centric and linear phase-encode orders at various flip angles. The arrow indicates the region of flow-related artifacts observed in MT asymmetry images acquired at high flip angle. **b**: MTR asymmetry (MTR_{Asym}) and percent signal changes (PSC_{MTAsym}) for the experimental results from all the subjects tested (solid lines) in comparison with the simulation results (dotted lines). The black and gray lines indicate centric and linear phase-encode orders, respectively, as indicated.

References : 1. Park and Duong, Magn Reson Med 2011;65:1578-1591. 2. Park and Duong, Magn Reson Med 2011;65:1702-1710. 3. Stanisz et al, Magn Reson Med 2005;54:507-512. 4. Hua et al, Magn Reson Med 2007;58:786-793 5. Zhou et al, Nat Med 2003;9:1085-1090