Effects of flip angle profile in T2 quantification using 3D dual echo steady-state (DESS)

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Introduction

Dual echo in the steady state (DESS) pulse sequence, which allows simultaneous acquisitions of two echoes within one TR, has evolved as an attractive technique for morphological imaging and quantitative T2 mapping [1]. With its compatibility with 3D acquisition, the T2 imaging method generates images with high signal-to-noise ratio (SNR) and high spatial resolution in a relatively short imaging time. Previous study shows that the flip angle dependence of DESS signal results in the systematic errors when computing T2 measurements [2]. Furthermore, it is well known that the actual flip angle across a 3D slab often decreases at the slab boundaries, and that the uniformity of the signal profile worsens as the designated flip angle increases [3]. Accordingly, in this study, we apply 3D DESS imaging for T2 measurement experiments to investigate the influence of the radio-frequency (RF) excitation pulse across slices within one slab, and discuss the effects of RF slab profiles.

Methods

Phantom imaging experiments were performed on a 3.0T Siemens Trio system using a 12-channel head coil. The image parameters were 200 mm FOV, 64 by 64 matrix size, 32 slices per slab, 5 mm slice thickness, 260 Hz/px BW and TR/TE1/TE2 = 30/3/57 ms, where TE1 and TE2 are the echo time of FID-like (S^+) and echo-like (S^-) images, respectively. To examine the T2 measurement, different flip angle (FA) values (10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°, and 90°) were used. The theoretical behavior of DESS signal intensity (S^+ and S^-) undergoing a continuous train of RF pulses was simulated for the same scanning parameters as described for the imaging experiments. The experimental and simulated T2 values corresponding to paired S^+/S^- derived from varied FA was subsequently calculated based on equation mentioned in [1, 2]. To further examine the relationship of 3D slab, two kinds of sinc-shaped excitation RF pulses were applied to DESS imaging separately, one with no side lobes used for conventional DESS imaging (RF1) and the other with 2 side lobes for better slab profiles (RF2). The RF pulse was simulated according to the RF parameters, and the profile of the flip angle distribution was then estimated by using Fourier transformation. A multiple spin echo (SE) sequence with 2000 ms TR and 32 contrasts (range from 16 to 512 ms, 16 ms step) was performed to determine the accurate T2 value.

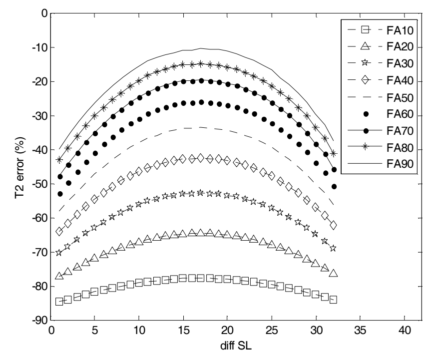

Fig. 1 T2 error along section direction.

Results

The ground true T2 value estimated from multiple SE is 81.34±0.80 ms. Figure 1 shows the T2 error of RF1 estimated from the comparison between DESS T2 and ground true value along the section direction with varied FAs (10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°, and 90°), indicating that larger flip angle leads to more accurate T2 measurement and dramatic T2 changes between slices (~30% differences between central slice and the most marginal one). On the contrary, less accurate quantification but better T2 consistency across slices (< 10% at FA10°) can be found for smaller flip angles. Figure 2 demonstrates the slab profiles at designated flip angle of 90°, where the black line, blue dotted line and blue asterisks represent the flip angle distribution, simulated T2, and estimated DESS T2 profile, respectively. All are normalized to the value at the slab center. Distinct patterns of flip angle distribution are presented, where the left column is the result obtained by sequence with RF1, and right column represents results from RF2. RF2 provides DESS T2 estimation with a wider range of consistency within central portion of slab and a substantial drop in the marginal slices, compared with the calculated T2 profile from RF1. Note that the estimated DESS T2s are in a good agreement with simulated T2 values for both datasets, and all T2 profiles are consistent with corresponding flip angle distribution as well. Figure 3 demonstrates the T2 maps of the phantom, where 6 out of 32 slices are chosen as example. The T2 map from the RF2 shows consistent contrast in 20 of 32 slices within central portion of slab, while only SL14 to SL20 could be viewed as similar contrast for T2 map from RF1.

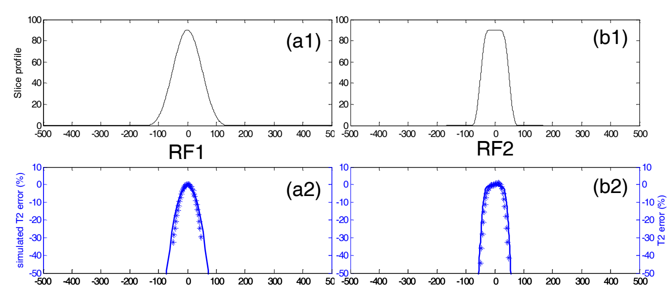

Fig. 2 Slab profiles. (a1, a2) FA distribution and simulated/estimated T2 profiles of RF1. (b1, b2) results of RF2.

Discussion and Conclusion

The results from this study demonstrate that the reliability of T2 quantification using 3D DESS could vary along the section direction due to flip angle profile imperfection, and could be increased by acquiring data with RF pulses having better slab profiles. With appropriate setting of the RF profile, the wider plateau of flip angle distribution as well as the DESS T2 estimations across slab could be achieved. There is some residual T2 underestimation on both sides of most marginal slice, which may be caused by inherent abrupt drop of RF property (RF2); nevertheless, the most part of slices could be viewed as consistent when using the modified RF pulse. It should be noted that, in conventional 3D DESS imaging, slices across slab have distinct estimated T2 values due to the corresponding flip angle distribution (RF1), which could impair the accuracy of comparison between slices even FA of 30° is used. We therefore conclude that, the modified 3D DESS technique provides benefit for better T2 quantitative imaging for clinical applications.

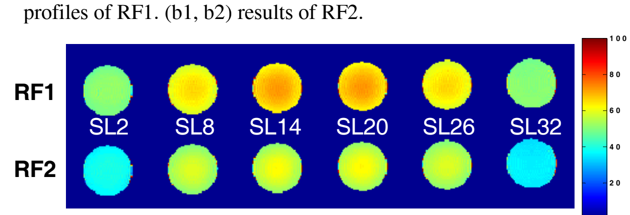

Fig. 3 T2 maps from RF1 (upper row) and RF2 (lower row).

References

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