Incidental Magnetization Transfer Contrast by Fat Saturation Preparation Pulses in Multi-slice MR Imaging: An Illustration of Look-Locker EPI Sequences

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Introduction

Recently, we observed the discrepancy of the signal intensities from a multi-slice inversion recovery (IR) Look-Locker echo-planar imaging (LL-EPI) sequence [1] with and without fat saturation (FS) preparation (prep) pulses (see Fig.1). It is suspected that the FS pulses, which were frequency selective but not spatial selective, induced such signal loss by magnetization transfer contrast (MTC). This unexpected (and undesirable) signal attenuation by FS prep pulses in multi-slice imaging would be problematic especially in quantitative MR imaging, such as relaxation time constant (T_1) measurement. In this study, MTC by the FS pulses in multi-slice LL-EPI was investigated. A reduction of signal intensity and bias on T_1 measurement caused by the FS prep pulses were demonstrated varying imaging parameters. As a solution, water-only excitation (WE) pulses, with spatial and spectral selection, showed the potential to minimize the signal attenuation and provide the unbiased T_1 measurement.

Methods

Three healthy subjects and a water phantom were scanned on a Siemens 3T Allegra scanner. Data were acquired using a single-shot LL-EPI sequences with the FS prep or WE pulses, and with various slice number (SN=1, 3, 5, 7, and 9). As a comparison, data without any preparation pulses (noFS) were also collected. Optimized imaging parameters, as described previously [2], were used for the T1 measurement: flip angle (FA) =16°, TR/TE = 400/14ms, and 25 different time points in each imaging plane acquired during 10s. Relative T_1 (rel.T_1) and relative signal intensity at the steady state (rel.M_{SS}) were obtained in the representative white mater (WM) and gray matter (GM), defined as measured T_1 and M_{SS} with FS prep or WE pulses, divided by T_1 and M_{SS} with noFS, respectively.

In addition, two data sets were collected using a conventional single-slice, non-selective IR EPI sequence with 10 different inversion times (TIs) ranging from 34 ms to 15000 ms, before and after IR LL-EPI scans. The other imaging parameters were: TR/TE = 3000/14 ms, FA=16°, FOV=220×220 mm^2, matrix=64×64, slice thickness = 5 mm.

For simulating the MTC effects by the FS prep pulses, a two-pool analytic mathematical description by Pike [1] was modified to consider multi-slice LL-EPI in this study. The fractional saturation in the free mobile (S_f) and restricted motion (S_r) proton pools were measured in WM and GM.

Results

Fig. 2 shows that the relative T_1 and M_{SS} of the water phantom and the representative regions of interest (ROIs) in WM and GM, with FS prep and WE pulses, as a function of slice number. It is shown that the signal loss by the FS pulses was increased in WM and GM ROIs as the slice number was increased. However, the water phantom did not show significant signal loss across the slice numbers. WE pulse did not induce the signal attenuation in WM and GM ROIs as well as the water phantom across the slice number. The similar tendency can be observed in T_1 measurement.

S_r and S_f were measured as 0.802 and 0.997 in WM, and 0.806 and 0.998 in GM, respectively. These results indicate that MTC effects were dominantly responsible for the signal attenuation and T_1 bias. The dependency of FA and TR on signal attenuation by FS pulses was simulated in GM with measured S_f and S_r values. Fig.3A shows that the signal loss is severer for smaller FA and larger slice number, with fixed TR=400ms. Fig.3B indicates that the signal loss is increased as shorter TR and larger slice number are used, with fixed FA=16°.

Fig.4 shows voxel-by-voxel T_1 values from the IR-EPI and the center slice of the three IR LL-EPI scans, respectively. T_1 mapping from IR LL-EPI with noFS and WE pulses show good slope with the baseline measurement from the IR-EPI. However, the correlation with the baseline measurement was improved with the WE pulse (r^2=0.98) compared with noFS (r^2=0.84). T_1 values from IR LL-EPI sequence with FS prep pulse were underestimated by approximately 15~22 % in the T_1 range of 800 ms to 15000 ms.

Discussion and Conclusion

In this study, we observed that the FS prep pulses invoked incidental MTC, resulting significant signal attenuation in multi-slice imaging. This MTC by FS prep pulses becomes severe when small FA, short TR, and large slice number are applied. It is shown that the incidental MTC induces a bias on T1 measurement when using IR LL-EPI sequence with FS prep pulses. However, WE pulses show the potential to minimize the signal attenuation and provide unbiased T_1 measurement without fat artifacts in MR images.

Another expected concern might be the functional MRI (fMRI) with FS prep pulses. The incidental signal attenuation by FS might can invoke a loss of contrast-to-noise ratio directly. From a simulation with typical fMRI parameters (TR=2s, FA=90° for T_1=1.5s, and 35 slices), FS prep pulse can reduce 17 % of signal loss compared to noFS. WE pulse might compensate the loss of CNR due to FS.

Reference 1. Look & Locker, RSI, 1970. 2. Shin et al., MRM, in press

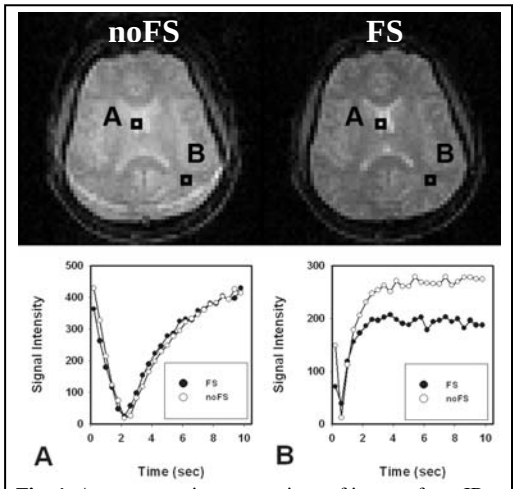

Fig. 1. A representative comparison of images from IR LL-EPI with and without FS prep pulses. Identical imaging parameters are applied. Black and white dots present the signal regrowth in the representative CSF (A) and WM (B) from the sequence with and without FS prep pulses, respectively.

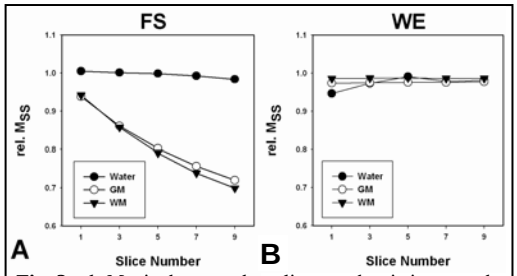

Fig. 2 rel. M_{SS} is decreased as slice number is increased, in WM and GM, but not in water. rel. T_1 shows the similar tendency.

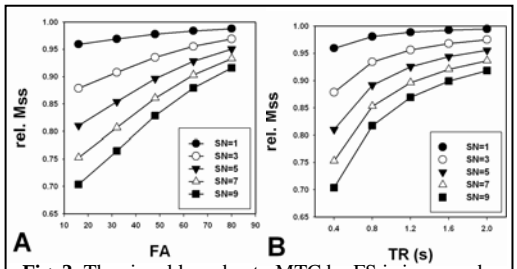

Fig. 3. The signal loss due to MTC by FS is increased as FA is decreased (A), TR is decreased (B), and the slice number is increased (A and B)

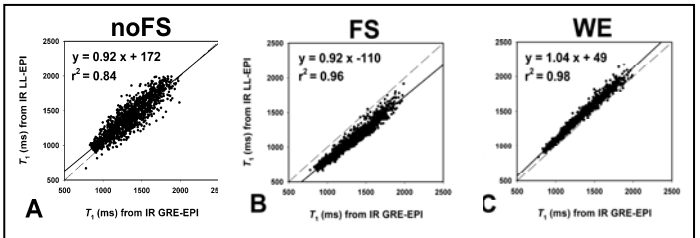

Fig. 4. Voxel-by-voxel comparison of T_1. The dash line is a unity (y=x).