SATURATION-RECOVERY SNAPSHOT FLASH REDUCES RF PULSE ANGLE INHOMOGENEITY ARTEFACTS IN DCE-MRI OF THE BREAST AT 3T.

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INTRODUCTION

Radiofrequency (RF) pulse angle inhomogeneity is a significant problem in breast MRI at 3T. Dynamic contrast-enhanced (DCE)-MRI of the breast with FLASH is susceptible to this RF inhomogeneity, and results in errors in the measurement of tumour enhancement ratio (ER) [1], where ER is a function of changes in relaxation rate (ΔR_1) and represents contrast agent concentration in the tissue. We have previously shown that saturation-recovery snapshot FLASH (SRSF) (Fig. 1a) reduces the errors in ER when complete saturation is achieved [2]. Extending this work, the aim of this study was to access the effectiveness of Hoffmann's method of saturation [3] in the presence of RF pulse angle inhomogeneity. This was done by performing a simulated DCE-MRI study and calculating ER.

METHODS

Hoffmann's method of SSRF was implemented. This sequence employs six nonselective 90° hard RF pulses separated by decreasing duration and different length of gradient spoiling pulses on all three gradient directions (Fig. 1b). A series of images of gel phantoms were acquired with centric k-space ordering (α/TR/TE/T_{REC} = 16°/8.3/4.6/150 ms). The effectiveness of this sequence in reducing the effect of pulse angle inhomogeneity was simulated by altering the pulse angles in the preparation pulse and the FLASH sequence to 50%, 75%, 125% and 150% of the nominal level. For comparison, images were obtained using a standard FLASH sequence (α/TR/TE = 35°/10/2.3 ms). All scans were performed using Philips X-series 3.0 T scanner and transmit-receive quadrature head coil (Philips Healthcare, Best, the Netherlands). This coil was chosen because it produces homogeneous pulse angles across the field-of-view.

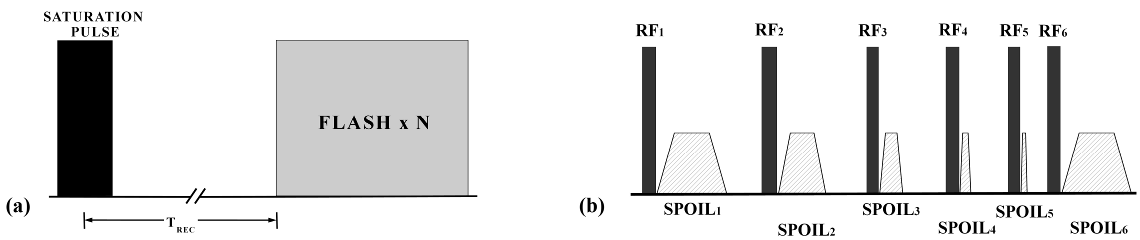

Figure 1 (a) Timing diagram for saturation-recovery snapshot FLASH (SRSF) and (b) Brix's sequence used as the saturation pulse in (a).

Computer simulation based on Bloch equation was developed using Matlab (Mathworks, Inc., Natick, USA). $M_x = M_y = 0$ and $M_z = M_0$ were used as initial magnetizations. An RF duration of 0.5 ms and spoiling gradients of 8, 6, 4, 2, 1 and 8 ms were implemented. The range of relative pulse angles (B_1/B_1^0) was 50% to 150%. Off-resonances between -3.5 and 3.5 PPM were chosen. These cover the ranges of inhomogeneities found in breast MRI at 3T [1,3].

RESULTS

A plot of the relative pulse angles produced using Hoffmann's SRSF is shown in Fig. 2. Fig. 3a and b show ER versus ΔR_1 for a simulated DCE-MRI acquisition using Hoffmann's SRSF and standard FLASH respectively.

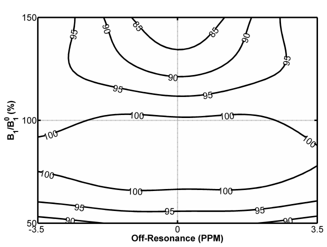

Figure 2 Simulated relative pulse angle (%) in the presence of RF (B_1/B_1^0) and B_0 (off-resonance) inhomogeneities produced using Hoffmann's method of SRSF.

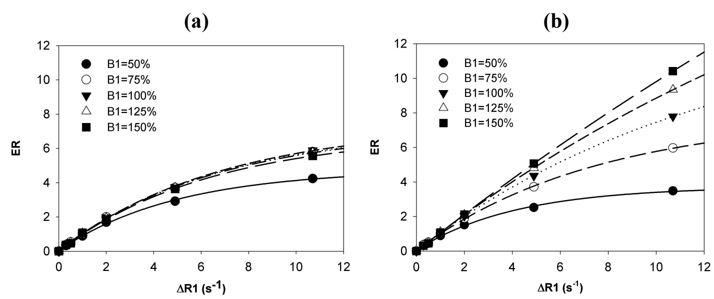

Figure 3 Enhancement ratio calculated in the presence of RF pulse angle inhomogeneity using (a) Hoffmann's SRSF and (b) standard FLASH.

DISCUSSION

We have shown that Hoffmann's method of SRSF reduces errors in ER estimation compared to a standard FLASH sequence. The computer simulation shows that SRSF using Hoffmann's method of train pulses produces a robust saturation in the presence of pulse angle and B_0 inhomogeneities. The ER data acquired from the simulated DCE-MRI acquisition broadly matches what is seen in simulation. However, there is a small discrepancy at a 50% reduction in pulse angle. Further work is required to identify the cause of this discrepancy. Implementing Hoffman's SRSF method may be a solution to minimise the effects of RF pulse angle inhomogeneity artefacts in quantitative DCE-MRI of the breast at 3T.

REFERENCES

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