Chemical-shift selective multislice imaging using the gradient reversal technique

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Introduction

In magnetic resonance imaging (MRI), the chemical shift phenomenon can produce severe artifacts of geometric shift or blurring according to imaging schemes. Instead of treating the chemical shift phenomenon as a source of artifact, many imaging technologies have been developed to acquire separate sets of images from different tissues having different resonance frequencies. The gradient reversal (GR) technique [1] is one of the chemical-shift selective imaging techniques, which was developed in 1987. Although it has not been widely used, Zoltan et al. [2] and Takahara et al. [3] have recently reported the effectiveness of this method for fat suppression at 3.0T and higher field. In this abstract, we expand the concept of the GR technique and demonstrate how to acquire multislice chemical-shift selective images with the GR technique.

Methods

In the GR technique, a simple concept of reversing the refocusing gradient in the spin-echo (SE) sequence was introduced so that only the on-resonance component could contribute to signal generation. This concept can be expanded with modification of the refocusing RF pulse such that the center frequencies (f_c) of the excitation RF pulse ($f_{c,90}$) and its refocusing RF pulse ($f_{c,180}$) have alternating polarity, i.e. $f_{c,180}=-f_{c,90}$. As in a conventional SE sequence, $f_{c,90}$ for selective multislice excitation can be determined with respect to the desired slice position. Thus, to acquire *n* slices of chemical-shift selective images, $f_{c,90}=f_0, f_1, f_2, \ldots f_n$ and $f_{c,180}=-f_0, -f_1, -f_2, \ldots, -f_n$ have to be used. By keeping the offset frequency (f_{off}) to be larger than the bandwidth of the RF pulse ($\Delta f/2$) as illustrated in Fig.2, signals from off-resonance components can be prevented from contributing to images.

To verify the proposed method, multislice SE sequence with reversed gradient technique was applied to a custom-made phantom which was filled with olive oil, soybean oil, methanol, and water, as shown in Fig.3. Sets of water-only and fat-only images were acquired at a 3T MRI system (ISOL technology, Korea) using the following parameters: matrix size = 256×256, number of slices = 10, slice thickness=2mm, TR=500, TE=30ms, FOV = 256×256 mm^2, and slice selection gradient amplitude of 13mT/m. Water-only images were acquired by setting the on-resonance frequency equivalent to the resonance frequency of water, whereas fat images were acquired by setting the on-resonance frequency equivalent to the resonance frequency of fat. The displacement of off-resonance component can be calculated by $z\_cs = 2\pi f\_off/(\gamma G\_z)$, where *z_cs*=chemical shift displacement, γ =gyromagnetic ratio, *G_z*= slice selection gradient, and *f_off*= frequency offset between two components. If the parameters are properly set so that enough amount of displacement is produced for off-resonance components, the final images can be acquired where signal is generated only by the on-resonance sources.

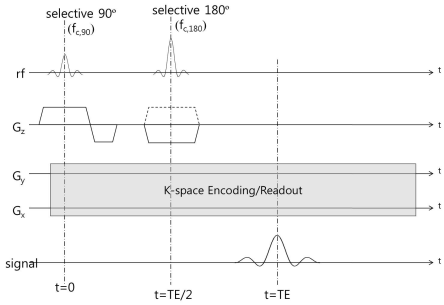

Fig 1. Sequence diagram of the proposed multislice GR technique

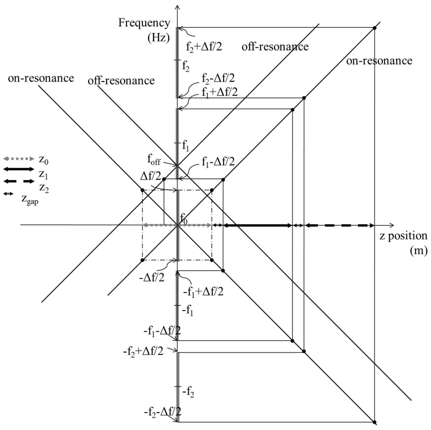

Fig 2. A concept diagram of the proposed multislice method

Results

Figure 3 shows images acquired with the proposed technique of gradient reversal and the selective RF pulses having alternating polarities. The center frequencies of the RF pulses were calculated by the resonance frequency of water (upper row) and fat (bottom row). As demonstrated by Fig.3, the gradient reversal method for multislice imaging produces spectrally selective images for water and fat with high accuracy. As it is known that a 3.5ppm difference (corresponding to ~450Hz at 3T) exists between water and fat, the displacement of the off-resonance components can be calculated as $z\_cs = 2\pi f\_off/(\gamma G\_z) \approx 2\pi \times 450\text{Hz}/(42.5\text{MHz} \times 13\text{mT/m}) \approx 5\text{mm}$. In other words, a shift of 5mm was produced for fat (water) when imaging was performed for water (fat) components due to chemical shift and as a result, no signal contribution was made from the off-resonance components.

Discussion

The GR technique is very effective for robust fat suppression, especially at high field strength because the amount of chemical shift increases as B0 field strength increases. Moreover, it can be especially beneficial to use the gradient reversal method for application areas where decomposition of spectrally different components is required. Since the GR technique does not require any additional scan time or increased SAR, it is recommended to use the GR method with spin-echo based sequences.

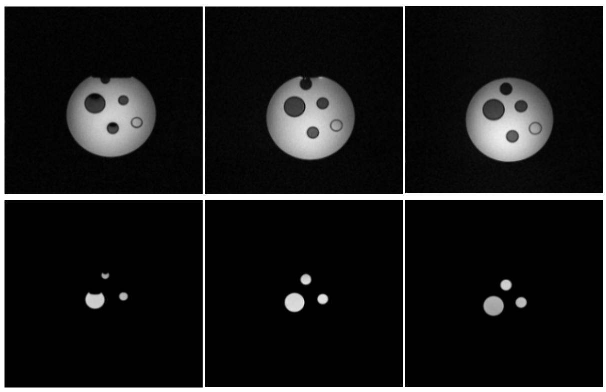

Fig 4. Water (upper row) and fat (bottom row) mages acquired with the proposed multislice GR technique.

Conclusion

Using the proposed multislice GR technique, chemical-shift selective imaging can be performed to separate signal sources having different resonance frequency components.

References

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Fig 3. A custom-made phantom used for the experiment