Chemical Shift Selective Missing Pulse Steady State Free Precession (MP-SSFP)

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A missing pulse steady state free precession (MP-SSFP) sequence was modified to perform chemical shift selective imaging by replacing one of the slice selective pulses with a chemical shift selective (CHESS) pulse. This sequence was applied to fat, water, and acetic acid phantoms, and results were evaluated with SNR measurements. Non-selected fat and water levels were below that of noise, and this was achieved with a total acquisition time of 6.1 sec while preserving slice selection capability. These results suggest a novel steady state technique for rapid chemical shift imaging.

Introduction

The missing pulse steady state free precession (MP-SSFP) [1] sequence distinguishes itself from conventional steady state sequences by dropping every third RF pulse and acquiring when the missing pulse would have occurred. Both of the remaining two RF pulses were originally proposed as slice selection pulses, but one of the pulses may be replaced with a chemical shift selective (CHESS) pulse. This creates a steady state sequence that is potentially both slice and chemical shift selective. The aim of this study is to evaluate the selective ability of this new steady state sequence.

Methods

The chemical shift selective MP-SSFP sequence is shown in figure 1. The second slice select pulse of an MP-SSFP sequence was replaced with a CHESS pulse. No gradients were applied during this pulse, which was centered at one of three frequency offsets: -225 Hz for fat imaging, 0 Hz for water imaging, and + 550 Hz for acetic acid imaging. Sequence parameters were as follows: τ (time between RF pulses and the acquired echo) = 7.6 msec, 256x256 image matrix, 256x256 mm FOV, BW = 360 Hz/pixel. The total acquisition time 6.1 sec, and a 9450 µsec CHESS pulse was used. The sequence was appliedto a slice with four phantoms: two acetic acid syringes, one oil phantom, and a water phantom. The work was performed on a Siemens Sonata 1.5 T scanner (Siemens Medical Solutions, Erlangen, Germany). The two acetic acid syringes were of different sizes, and were placed at two different sagittal planes which both included the water phantom. An axial slice was acquired with each of the three frequency offsets. Two sagittal images, one for each acetic acid phantom, were also acquired, using the frequency offset for acetic acid imaging. The axial slice images were acquired a second time with τ = 10 ms. With this sequence, 14040 µsec CHESS pulse was used, and the total acquisition time was 8.0 sec. SNR measurements were made of each phantom in each image. The fat- and water-selective sequences were also applied to the knee of a healthy volunteer.

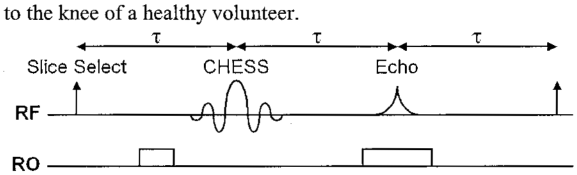

Figure 1. Chemical Shift Selective MP-SSFP Sequence.

Results

With τ = 7.6 msec, SNR values for the selected phantoms were 71.4 for fat, 86.7 for water, and 6.7 for acetic acid. Non-selected fat and water phantoms were barely distinguished in the background noise (SNR = 0.3). SNR values of selected phantoms were similar with the sequence requiring 8.0 sec, but non-selected water and fat phantoms could not be distinguished from the background noise. The two acetic acid syringes were independently imaged on two separate sagittal slices, while other phantoms were suppressed.

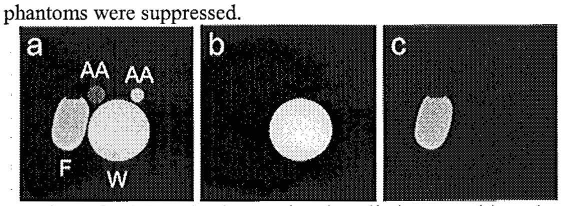

Figure 2. A FLASH image showing all phantoms (a), and images acquired with chemical shift selective MP-SSFP with the center frequency set for water (b) and fat (c).

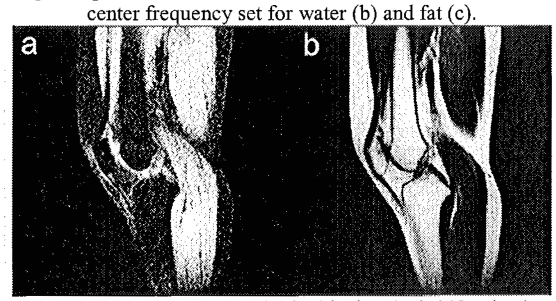

Figure 3. Knee images acquired with chemical shift selective MP-SSFP on a healthy volunteer. Center frequency was set for water (a) and fat (b).

Discussion

The MP-SSFP sequence can be described as a steady state sequence with two different RF pulses per repetition. While both RF pulses are typically applied to the same slice, they may be set to select two different sets of spins. The structure of the MP-SSFP sequence would allow only the spins at the intersection of the two spin sets to refocus at the echo time. Other spins would either be excluded by both RF pulses or dephased at the echo time. This technique relies on the selective excitation of spins, as opposed to the saturation of signal from undesired spins. This concept has been applied for spin echo sequences, but MP-SSFP allows this to be applied to a steady state technique. The potential utility of this method is demonstrated in Figure 3, in which virtually complete fat suppression is observed.

Fat, water, and acetic acid were selectively imaged in this study, but the center frequency of the RF pulses may be adjusted to any range of frequencies. The use of a CHESS pulse results in a near bandlimited frequency response to this sequence, as opposed to a periodic profile seen in other chemical shift selective steady state sequences [2]. Chemical shift resolution is limited by the duration of the CHESS pulse, and spin behavior may deviate from these results with the use of longer RF pulse durations.

Conclusion

Rapid and effective chemical shift imaging is achieved with the use of CHESS pulses in MP-SSFP.

References

[1] Patz S, et al., Magn Reson Med; 10(2): 194-209.
[2] Vasanawala SS, et al., Magn Reson Med; 42(5): 876-83.