Lipid Suppresion using Spectral Editing of Fast Spin Echo Trains

A. J. Wheaton[1], J. B. Murdoch[1], and R. Anderson[1]
[1]Toshiba Medical Research Inst. USA, Mayfield, OH, United States

INTRODUCTION

In MR spectroscopy, the BASING and MEGA techniques have been used to edit water and/or fat from spectra [1,2]. These techniques work by including a spectrally-selective rf pulse that inverts water and/or lipid resonances and leaves metabolites of interest [1.9 – 3.6 ppm] undisturbed.

The BASING / MEGA technique has the following advantages: time-efficiency because it does not use a prepulse, T1-insensitivity because it operates on transverse rather than longitudinal magnetization, and good B1-robustness because it uses a refocusing pulse [180°] which is less sensitive to B1 error than a saturation pulse [~90°]. However, using BASING / MEGA technique for MR imaging in its original spectroscopy form [inverting fat and crushing its signal with opposing gradients while not refocusing water] would create a very long first echo.

REFUSAL TECHNIQUE

We have incorporated the general BASING / MEGA idea in an implementation conducive to imaging. We developed a technique for rf echo train-based sequences like FSE called REFUSAL [**REF**ocusing **U**sed to **S**electively **A**ttenuate **L**ipids]. The first rf pulse of the echo train is replaced with a spectrally-selective phase-modulated pulse [Fig 1]. The spectrally-selective rf pulse allows desired resonances [water] that are fully refocused to evolve in the echo train. Unwanted resonances [lipid] are minimally refocused, dephased by the crusher, and thus "refused" from propagating in the echo train. The first echo is discarded.

REFUSAL RF PULSE

The design of the phase modulated REFUSAL rf pulse includes several features favorable for MR imaging. The spectral selection profile includes a sharp transition between water and lipid to maximize the refocusing BW for water while maintaining near zero refocusing for a wide range of lipid chemical shifts [Fig 2]. Also, the REFUSAL pulse is designed to produce uniform behavior over a wide range of B1 [Fig 2]. To incorporate these rf performance features, the duration of the REFUSAL pulse is relatively long compared to imaging pulses in the echo train. In our example, it was 8.0ms [compared to 1.3 ms for imaging pulses]. This design increases the minimum echo spacing. If a longer echo spacing [10+ms] is not desirable for the application, design tradeoffs can be made with the REFUSAL pulse to shorten its duration. Alternatively, the initial echo spacing can be extended a small amount followed by a train of regular short echo spacings.

METHODS

The lower lumbar of a male volunteer was scanned on a Toshiba 3T whole-body research system. Sagittal REFUSAL images were acquired with the following parameters: TE/TR = 78/3000 ms, ETL = 27, matrix = 256 x 256, FOV = 28 x 28 cm, one 5mm thick slice, readout BW = 390 Hz/pixel. In this example, we used an initial echo spacing of 13.0ms followed by a train of 6.5ms echo spacings. For comparison, TE-matched FSE images with CHESS fat suppression were acquired with identical parameters. To test the response of REFUSAL to a range of B1 inhomogeneity, the experiment was repeated for a range of B1 amplitudes of the REFUSAL pulse [60% to 140% of ideal, in steps of 10%]. The analogous experiment was performed on the CHESS data by adjusting the amplitude of the CHESS prepulse. In the B1 = 100% images, SNR was measured in the intervertebral discs for both techniques.

RESULTS

REFUSAL generates images with CHESS-like image contrast without the evident B1-sensitivity of CHESS [Fig 3]. SNR of REFUSAL was ~10-15% lower than CHESS. REFUSAL produced uniform fat suppression over a range of B1. For low B1, CHESS did not completely suppress fat. For high B1, CHESS produced nonuniform fat suppression. In some regions, the overtipped CHESS pulse reduced water signal in the vertebral discs.

DISCUSSION

Due to its spectrally-selective refocusing pulse, REFUSAL is limited to single slice or 3D acquisitions. However, the spectrally-selective first pulse could be replaced by a spatial-spectral pulse to enable multislice acquisitions. Like any spectrally-selective technique, REFUSAL has the disadvantage of potential B0 sensitivity. Also, REFUSAL loses some SNR due to the discard of the first echo data, possible loss of some echo coherences or isochromat dephasing due to diffusion [if the initial echo spacing is extended], and magnetization transfer effects from the spectral side lobes of the REFUSAL pulse.

CONCLUSION

REFUSAL includes the T1- / B1-robustness and time-efficiency advantages of BASING / MEGA but in an implementation conducive to MR imaging. REFUSAL produces uniform fat suppression over a large FOV with minimal signal loss for a wide range of B1 homogeneity.

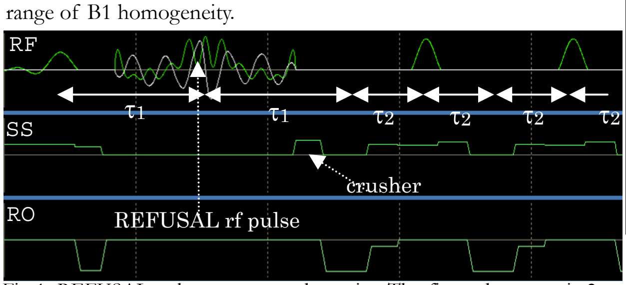

Fig 1. REFUSAL pulse sequence schematic. The first echo space is $2\tau_1$ and the subsequent echo spaces are $2\tau_2$.

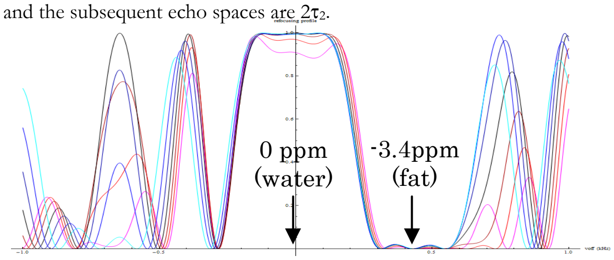

Fig 2. Refocusing profile for REFUSAL pulse. Multiple overlaid plots indicate refocusing angle for range of 70% to 130% of ideal B1. For the water resonance, 70-80% B1 produces slightly less than full refocusing, but 90-130% B1 produces nearly identical full refocusing. For fat, the full range of B1 produces near zero refocusing.

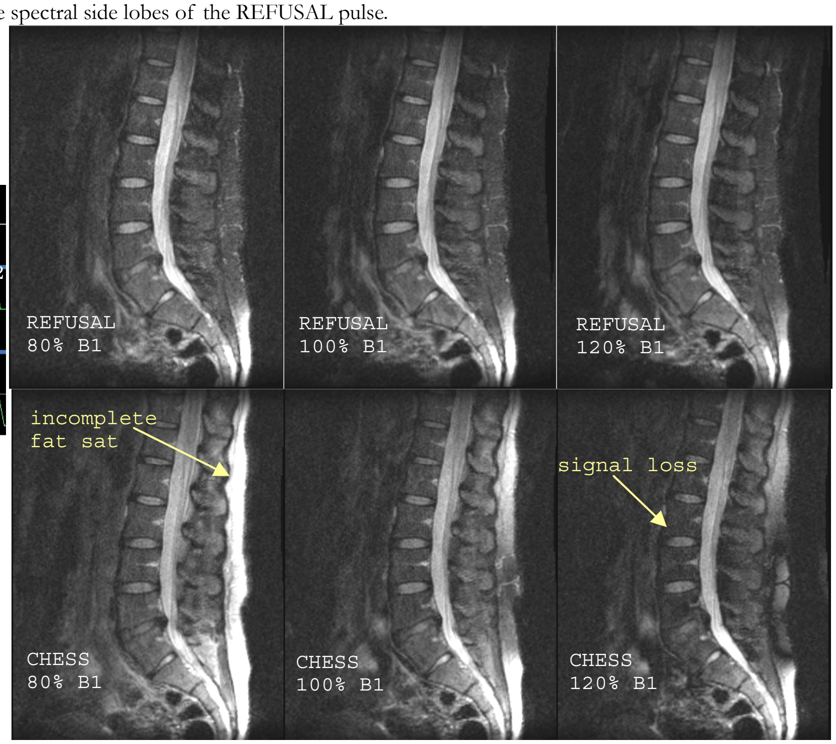

Fig 3. Comparison of B1 sensitivity of REFUSAL and CHESS over a range of B1 [80 – 120% of ideal]. Areas of poor fat suppression and signal loss are identified on CHESS images.

REFERENCES: **1**. Mescher M, Tannus A, Johnson O, Garwood M. J Magn Reson A 1996; 123:226-229. **2**. Star-Lack J, Nelson S, Kurhanewicz J, Huang L, Vigneron D. Magn Reson Med 1997; 38:311-321.