# Rapid Fat Suppressed Imaging: Application to the Cartilage and the Breast

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## INTRODUCTION

Fat suppression is an important MRI procedure widely employed in many research and clinical applications. Fat suppression reduces chemical shift artifacts, enhances lesion conspicuity, and improves the dynamic range of interested lean tissues. With the development of modern MR technology, rapid short-TR, gradient echo imaging techniques have gained popularity due to their ability to obtain high quality images in short acquisition times. Rapid fat suppression in these sequences is a challenge due to the relatively short $T_1$ and long $T_2$ of fat. A novel rapid fat suppression strategy has been described recently to achieve rapid and effective fat suppression (1). The novel approach combines fat presaturation with sustained water-selective, spatial-spectral excitation (SSE) in a segmented gradient echo shot. Therefore, a long echo-train-length (ETL) can be achieved without the introduction of severe artifacts from fat into the resultant images. An implementation of the novel strategy, which combines fat presaturation using spectral partial inversion recover (SPIR) with water selective SSE (1-1), has been tested and verified at 1.5T. In this work, a different implementation of this strategy is introduced and tested on cartilage and bilateral breast imaging.

## METHODS AND RESULTS

### 1. Pulse Sequences

In place of a continuous RF pulse to achieve fat presaturation, short, binomial RF pulse train was used (Fig. 1). The pulse train was design to achieve fat selective excitation. The pulse-pulse interval was 2.3 ms for 1.5 T. The binomial pulse train was implemented using Research PrePulse (REPP) available on Philips scanner (Intera), and the sequence is therefore referred to as REPP-SSE TFE. A female subject was scanned at the knee and breast to test the fat suppression efficacy.

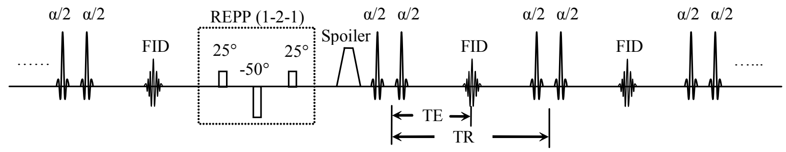


**Fig. 1.** Fat suppressed REPP-SSE TFE sequence, which combines fat-selective presaturation with sustained 1-1 binomial RF pulses for water excitation. An RF spoiled gradient echo readout train, or a balanced steady-state free precession (b-SSFP) readout train can be used for data acquisition. A low-high (or centric) phase profile ordering has to be used for optimal fat suppression.

### 2. Fat Suppressed Cartilage Imaging

Both 3D, RF spoiled gradient echo readout (T1W) and 3D, b-SSFP readout were tested on knee imaging with the following parameters: 70 axial slices, FOV = 200mm, MS = 400×400. For the T1W sequences, TR/TE/FA = 14.0ms/5.1ms/15°, and readout bandwidth = 49kHz. For b-SSFP readout, TR/TE/FA = 7.8ms/3.3ms/30°, and readout bandwidth=228.9kHz. Partial Fourier echo readout was also used in both sequences to achieve decreased TR and TE. Both sequences achieved strong and homogeneous fat suppression by using the novel fat suppression strategy, as seen in Fig. 2. Since b-SSFP is $T_2/T_1$ weighted, synovial fluid has a bright signal in Fig. 2(b). The high contrast between synovial fluid and articular cartilage improves the conspicuity of any potential cartilage lesions. The synovial fluid signal in REPP-SSE TFE images indicated by the white arrow in Fig. 2a is relatively dark compared with bright cartilage. Therefore, the REPP-SSE TFE is validated to offer strong $T_1$-weighting for cartilage imaging.

**a.** REPP-SSE T1W TFE (4:03) **b.** REPP-SSE b-SSFP (2:38)

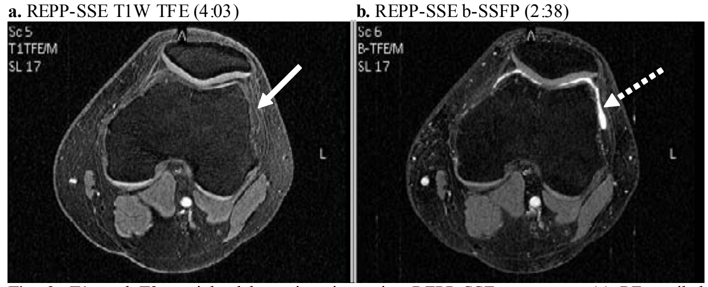


**Fig. 2.** T1- and T2- weighted knee imaging using REPP-SSE sequences. (a) RF spoiled gradient echo readout train was used to achieve T1-weighted images. Synovial fluid signal is suppressed in REPP-SSE TFE images compared with cartilage signal. (b) B-SSFP readout train was used to achieve strongly $T_2$-weighted contrast. High contrast between articular cartilage and synovial fluid (dashed arrows) is obtained.

### 3. Fat Suppressed Bilateral Breast Imaging

Fat suppression in bilateral breast MRI is challenging since the imaging FOV is large, resulting in worse overall field homogeneity. Also, cardiac and respiratory motion is a fundamental problem for bilateral breast imaging. As above, REPP-SSE TFE with RF spoiled gradient echo readout was applied. 60 axial images were obtained with free breathing, and the measured slice-thickness was 4 mm with 2 mm overlap. Imaging FOV was 33 cm, and matrix size was 512 × 512. The REPP-SSE TFE sequence in this case had TR/TE/FA = 11.0 ms/3.8 ms/15°. In the first scan, the frequency encoding direction was along anterior-posterior (AP) direction to minimize respiratory motion artifacts, and SENSitivity Encoding (SENSE) technique (2) was employed with SENSE factor = 2 along left-right (LR) direction. The scan duration was 1:52 (min:sec). Notably, respiratory and cardiac motion artifacts are not severe along phase encoding direction (Fig. 3a). Therefore, the frequency-direction was set to LR direction in the second scan. rFOV=50% instead of SENSE was used to achieve the same scan duration. The resultant images suffer little contamination from respiratory and cardiac motion in both the breast and axillae regions (Fig. 3b). For both acquisitions, homogeneous fat suppression was achieved.

**a.** REPP-SSE TFE w/ SENSE (1:52) **b.** REPP-SSE TFE w/o SENSE (1:52)

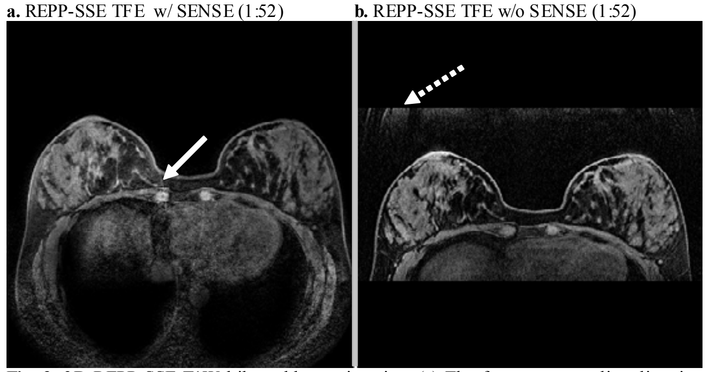

**Fig. 3.** 3D REPP-SSE T1W bilateral breast imaging. (a) The frequency encoding direction was set to AP, and SENSE=2 was used along the LR direction. rFOV=100% had to be used to cover two breasts. The images suffer slightly from SENSE artifacts (solid arrow). (b) The frequency encoding direction was set to LR, and the first phase encoding direction was AP. rFOV=50% was used without losing breast coverage. Only a slight fold-over artifact is observed in the anterior air region, which does not contaminate the breast (dashed arrow).

## DISCUSSION

It has been demonstrated that robust and time efficient fat suppression can be achieved by using binomial RF pulses for fat presaturation in combination with short, sustained water-selective excitations. Therefore, both short TR and TE can be achieved, making this technique less sensitive to motion and $T_2^*$ effect. Since the SSE (1-1) pulse train used in each TR cycle is short, relatively low readout bandwidth can be used to achieve high SNR for RF spoiled gradient echo readout. B-SSFP readout can inherently offer high SNR. Therefore, high readout bandwidth can be used to decrease TR. Short-TR b-SSFP sequences are also less sensitive to motion and $B_0$ inhomogeneity. The superior SNR, as seen in Fig. 3b, motivates the use of parallel imaging techniques to improve temporal resolution. In summary, we have presented here some preliminary results on the usefulness of the novel fat suppression technique in cartilage and bilateral breast imaging, and some possible approaches to enhance imaging speed. Further clinical studies are warranted.

**References**

1. Peng Q, et al., "Novel Rapid Fat Suppression Strategy with Spectrally Selective Pulses", MRM, 2005; 54(6):1569-74.
2. Pruessmann KP, et al., "SENSE: sensitivity encoding for fast MRI", MRM, 1999; 42(5): 952-962