

# PSIF Imaging with Outer Volume Suppression for Percutaneous Interventions

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## Introduction

In interventional MRI, fast pulse sequences are necessary to follow motion of medical instruments. In MR-guided percutaneous interventions with needles the needle artifact and the surrounding anatomy need to be visualized with high spatial and temporal resolution. Image acquisition can be accelerated significantly by restricting the field of view in phase-encoding direction; however, this might result in unwanted aliasing. A solution can be outer volume suppression (OVS) or inner volume excitation (IVE) [1, 2]. In a missing pulse sequence, IVE has been combined with a steady state pulse sequence [3]. Unfortunately, this leads to a drastic signal loss in the IVE images compared to a similar pulse sequence without IVE preparation. In this work an echo-shifted steady state free precession pulse sequence was used to create a T2-weighted contrast. The sequence was combined with OVS to restrict the phase encoding direction and, thus, to accelerate the image acquisition.

## Materials and Methods

The echo-shifted steady state sequence PSIF (time-reversed fast imaging with steady state precession) was implemented on a clinical 1.5 T MR system (Magnetom Symphony, Siemens, Erlangen, Germany). The image acquisition was segmented, so that after the acquisition of  $N$  k-space lines a dummy TR interval (SAT) for the suppression of the MR signal outside the FOV could be applied. Figure 1 shows a schematic of the pulse sequence.

In the SAT section of the sequence no image encoding gradients are applied, but the gradient moments in all three directions have the same values as over one image acquisition TR to maintain the steady state in the imaging FOV. Instead, a  $90^\circ$  saturation pulse with slice selection in phase encoding (PE) direction is placed after the excitation pulse to saturate the spins outside the FOV. A spoiler (SP) after the saturation pulse further dephases out-of-FOV signals. To suppress signals from both sides of the FOV, two SAT sections were used.

To increase the time-efficiency of the implementation, the number  $N$  of k-space lines was chosen between 3 and 15. Furthermore, k-space reordering was used to minimize the distance between subsequent PE steps which significantly reduces eddy-current related artifacts.

The OVS-PSIF sequence was applied with the following parameters: TR = 11 ms, TE = TR+5.5 ms,  $\alpha = 40^\circ$ , matrix =  $256^2$ , BW = 250 Hz/px,  $N = 7$ . Images of a phantom with T1 = 2700 ms and T2 = 2000 ms (region 1 depicted in Fig. 2a) and T1 = 300 ms and T2 = 120 ms (region 2) and of a volunteer's abdomen were acquired.

## Results and Discussion

Figure 2b shows the phantom image with both excellent suppression of the outer volume and the same image contrast as the PSIF sequence without OVS. The signal profile in Fig. 2c, along the dashed line in figure 2b, demonstrates the very good signal-to-background ratio of 65. With a reduction of the phase FOV of 20 %, an acquisition time of 210 ms could be achieved. Figure 3 shows sagittal and transverse volunteer images acquired with OVS-PSIF. Here, only a 50% FOV reduction was used, which resulted in an acquisition time of 800 ms. Outside the FOV in PE direction, minor signal artifacts from incomplete suppression are visible, which do not visibly interfere with the actual image.

With typical imaging parameters the OVS-PSIF sequence allows reducing the measurement time to only 28% of the acquisition time for a full image without compromising the steady state contrast. In combination with other acceleration techniques such as partial Fourier and parallel imaging, even higher reduction factors could be achieved.

## References

- [1] Pisani, L. et al., Magn Reson Med **57**, 297-307 (2007)
- [2] Zimmermann, H. et al., Magn Reson Med **56**, 481-8 (2006)
- [3] Hwang, KP. et al., J Magn Reson Imag **19**, 124-32 (2004)

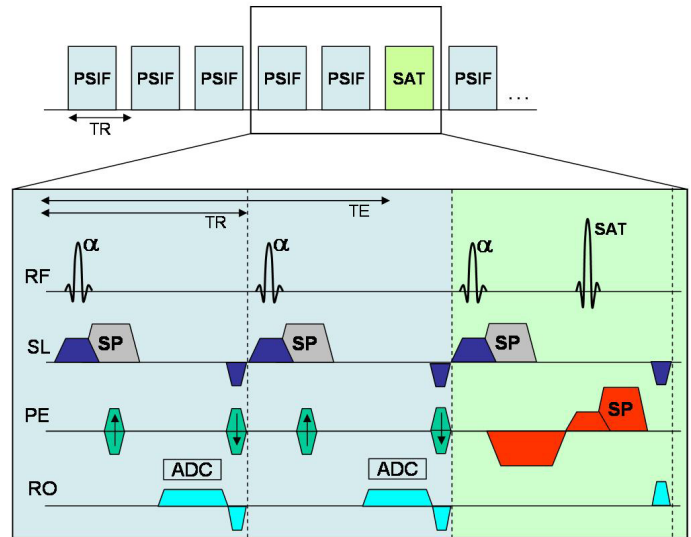


Fig. 1: Top: Timing of the OVS-PSIF sequence, below: detailed view of both imaging (PSIF, blue) and saturation (green) section.

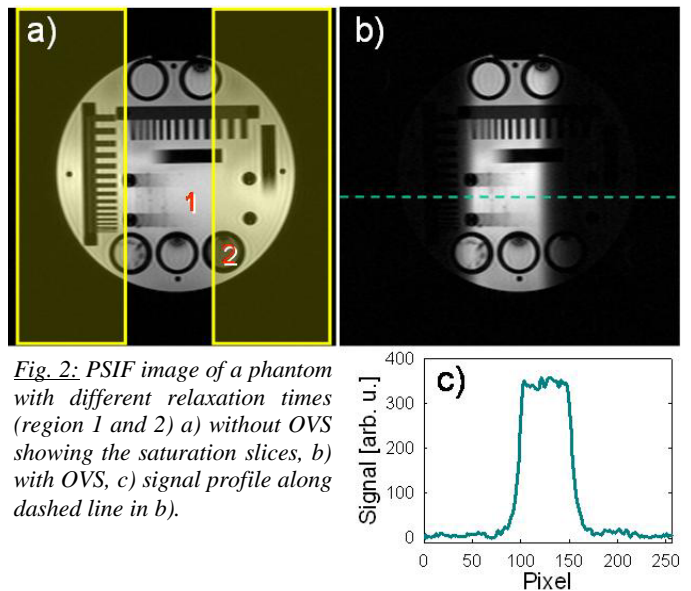


Fig. 2: PSIF image of a phantom with different relaxation times (region 1 and 2) a) without OVS showing the saturation slices, b) with OVS, c) signal profile along dashed line in b).

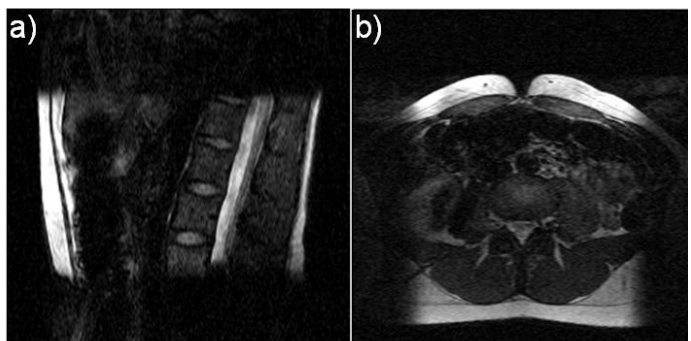


Fig. 3: a) Sagittal and b) transverse volunteer images acquired with OVS-PSIF.