Outer Volume Suppression for Three Different Steady State Sequences used in Percutaneous Interventions

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Introduction

In interventional MRI, fast pulse sequences are necessary to follow the 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 (FOV) in phase-encoding direction; however, this might result in unwanted aliasing. Two solutions are outer volume suppression (OVS) or inner volume excitation (IVE) [1]. In a missing-pulse sequence, IVE has been combined with a steady-state pulse sequence [2]. Unfortunately, this leads to a drastic signal loss in the IVE images compared to a similar pulse sequence without IVE preparation. In [3] an OVS steady-state free precession sequence (PSIF) was presented which restricts the phase encoding direction without losing steady state. In this work the PSIF-OVS sequence was optimized in time efficiency and flow compensation (FC) was implemented. Additionally, FLASH-OVS and trueFISP-OVS sequences were developed to provide fast imaging with 3 different contrasts during percutaneous interventions.

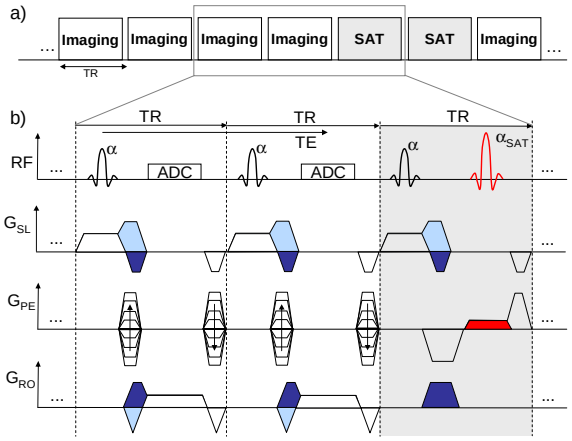

Fig.1: a): Timing of the OVS-PSIF-sequence, b): detailed view of both imaging and saturation (grey) section. Light blue filled gradients: FC in RO direction, dark blue filled gradients: FC in SL direction.

Materials and Methods

OVS-sequences were 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 new PSIF pulse sequence. The user can choose between FC in SL or in RO direction (dark or light blue marks in fig.1).

In the SAT section of the sequence a saturation pulse with slice selection in phase encoding (PE) direction is placed after the excitation pulse to saturate the spins outside the FOV. Simulations of the magnetization dynamics demonstrated that α_{SAT}=120° leads to the highest saturation at k-space center. A spoiler (SP) following the saturation pulse further dephases out-of-FOV signals. No image encoding gradients are applied in the SAT section, but the gradient moments in all three directions have the same values as over one imaging section to maintain the steady state in the imaging FOV. To suppress signals from both sides of the FOV, two SAT sections were used. The OVS-PSIF sequence provides a T2-like contrast and was applied with the following parameters: TR = 8 ms, TE = TR+4 ms, α = 40°, matrix = 256^2, BW = 250 Hz/px, *N* = 7.

For the OVS-FLASH sequence the imaging TR-interval contains conventional spoiled gradient echo timing with spoiler gradients in slice selection and read out direction. Additionally, rf-spoiling is used. To get a T1 contrast same parameters were used except a flip angle of 15°.

The SAT section of the trueFISP-OVS sequence was embedded into α/2-preparation during TR/2 intervals to store the magnetization on z-direction [4]. This technique was used because of eddy current related artifacts due to differing gradient scheme in the SAT section. Imaging parameters were: TR = 5.4 ms, TE = 2.7 ms, α = 70°, matrix = 256^2, BW = 390 Hz/px, *N* = 7.

Images of phantom solutions with tissue-equivalent relaxation times (Fig. 2a) are acquired. Signal (red box in Fig. 2) - suppression (green box) - ratios (SSR) in consideration of noise (blue box) were measured. Finally, a percutaneous intervention on a pig's liver was performed.

Results and Discussion

Figure 2 shows the phantom images with excellent suppression of the outer volume. A SSR of more than 15 for PSIF and FLASH and about 7 for trueFISP was observed. The needle tip position during an animal experiment (Fig. 3) is clearly visible for all sequences. Here, a 32% FOV reduction was used, which resulted in an acquisition time of 500 ms. With these technique a 12% FOV reduction leads to an image update rate of about 5 images/s. Therewith, MR-guided interventions on moving organs like liver biopsies can be performed reliably.

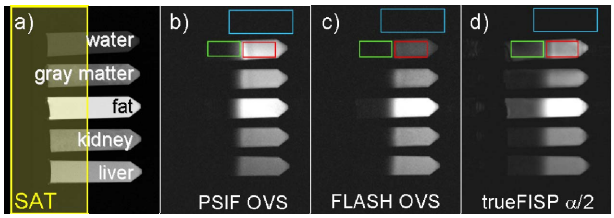

Fig. 2: a) Localizer with SAT region and b)-c) OVS-Imaging of six phantoms (H_2O, Agar, $CuSO_4$) with T1 and T2 similar to tissues indicated in a).

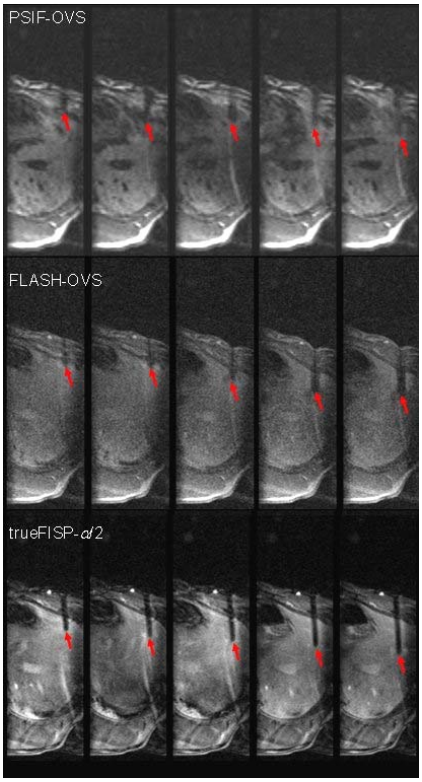

Fig. 3: Percutaneous intervention on a pig liver. The red arrows mark the needle tip.

References

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