Fat Suppression for Non-contrast-enhanced Peripheral Angiography: Phase-sensitive versus IDEAL SSFP

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Introduction: MR angiography is a valuable tool in the diagnosis of vascular diseases. Non-contrast-enhanced flow-independent peripheral angiograms can be produced with magnetization-prepared balanced SSFP if the bright fat signal is suppressed [1]. However, poor fat suppression and banding artifacts can be observed with field inhomogeneity (e.g., over large FOVs). In this work, we compare two reliable fat/water separation methods: phase-sensitive (PS) [2] and multi-echo IDEAL [3,4] SSFP, both compatible with dual-acquisition complex-sum SSFP [5] that effectively reduces the banding artifacts.

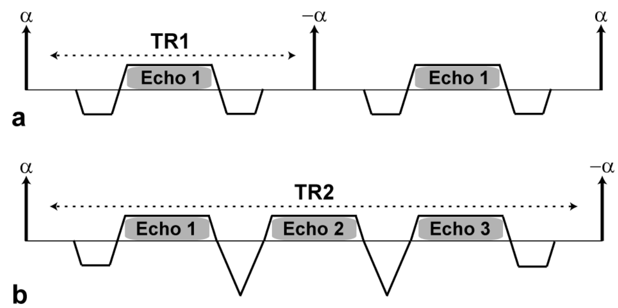

Figure 1. The pulse sequence diagrams for single-echo PS-SSFP **(a)** and multi-echo fly-back IDEAL **(b).**

Methods: For both techniques, an initial inversion recovery (IR) to reduce the synovial fluid signal is followed by a segmented BIR-4 T2-prep pulse [6] to reduce the muscle signal. After suppressing the transient oscillations by gradually increasing the tip angle [7], the generated contrast is effectively captured with centric phase-encode ordering and segmented k-space acquisitions. Magnetization is prepared again at the beginning of each segment to restore the contrast [1].

Fig. 1 shows the diagrams for PS-SSFP (TR = TR1) and IDEAL (TR = TR2 > TR1). To achieve a fair comparison between the techniques, we equated the total scan times and the acquisition times for each k-space segment by using different parallel imaging (ARC [8]) accelerations. Three volunteers were scanned to produce lower leg and foot angiograms on a 1.5 T GE scanner with the following parameters: 1 mm^3 isotropic resolution, $\alpha = 90^o$, FOV = 32 cm (lower leg) and 27 cm (foot), ±125 kHz BW, 1.8 s IR, 80 ms T2-prep, and a 3 s inter-segment recovery time. The magnetization was prepared every 6 s for the lower leg and 3.3 s for the feet. While TR1 = 5 ms and TR2 = 10 ms, the 2D acceleration factors were 1.4 for PS-SSFP and 2.8 for IDEAL.

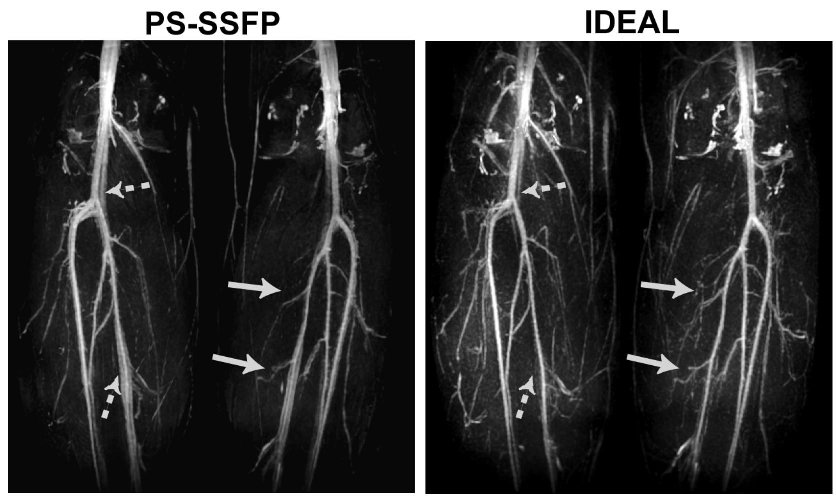

Figure 2. Maximum-intensity projections (MIPs) of the lower leg. IDEAL enhances the small vessel depiction (solid arrows) and the venous suppression (dashed arrows).

Results: Figs. 2 and 3 show the images of the lower leg and feet acquired with PS-SSFP and IDEAL. Table 1 lists the mean SNR and contrast measurements. PS-SSFP has higher blood-muscle contrast, which may be attributed to the increased MT effect with its shorter TR [9]. However, partial volume artifacts in PS-SSFP cause small vessel loss, whereas IDEAL enhances the small vessel depiction. IDEAL also achieves better venous suppression due to its longer TR [10].

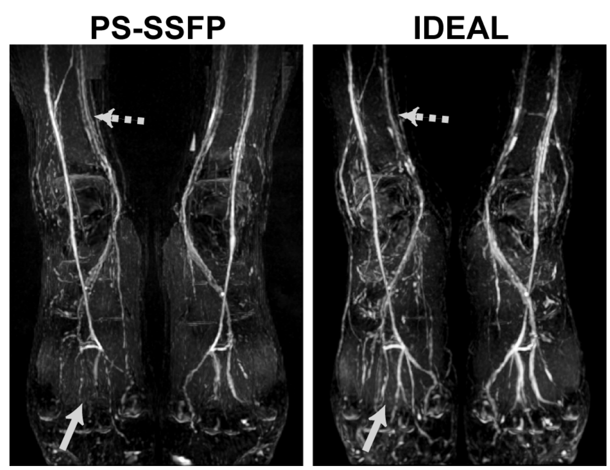

Figure 3. MIPs of foot angiograms. IDEAL enhances small vessel depiction and improves venous suppression as shown by the solid and dashed arrows respectively.

	B/M_1	A/V_1	SNR_1	B/M_2	A/V_2	SNR_2
PS-SSFP	3.65	1.29	16.76	2.66	1.23	13.76
IDEAL	2.75	1.62	19.77	2.15	1.51	19.51

Table 1. Blood/muscle (B/M) and arterial/venous (A/V) contrast as well as arterial blood SNR. The first and second sets of measurements were performed on the anterior tibial and dorsalis pedis arteries respectively.

Conclusion: Both methods are effective at suppressing fat. However, while PS-SSFP is simpler and faster, IDEAL offers enhanced visibility of small vessels and improved venous suppression. This can be important in the extremities, where partial-volume effects are significant and pairs of deep veins course adjacent to each artery.

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