Non-Contrast-Enhanced Angiography at 3T using SSFP and "Dixon" Fat-Water Separation

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Introduction: In contrast-enhanced angiography below the knee, the short time interval between arterial and venous enhancement limits the spatial resolution of the acquisition. Even with restricted acquisition duration, arterial conspicuity is often compromised by the superposition of enhancing deep veins [1]. Recent work has explored high-resolution, non-contrast-enhanced angiography methods using balanced SSFP acquisitions [2, 3, 4, 5]. To separate arteries from veins, these techniques rely on T_2 differences between arterial and venous blood [6]. Results using an SSFP method with intermittent fat suppression (FS-SSFP) [7] for non-contrast-enhanced angiography have demonstrated that arterial-venous separation is improved at 3T compared to 1.5T [4, 5]. However, the periodic spectrally-selective inversions and subsequent discarded excitations designed to reestablish the steady-state reduce the scan efficiency of this method. In addition, the degree of fat-suppression achieved over a large FOV can vary spatially due to B_0 and B_1 inhomogeneities, which are more severe at 3T compared to 1.5T. It is also hypothesized that the periodic interruption of the steady-state may negatively impact the achieved arterial-venous contrast since arterial-venous differences in the SSFP transient signal are reduced compared to the steady-state signal [8].

In this work, we investigate a 3T balanced-SSFP acquisition using "Dixon" fat-water separation (Dixon-SSFP) [9] to generate non-contrast-enhanced angiograms below the knee. This method is robust in the presence of B_0 and B_1 inhomogeneities. In addition, a true steady-state is established, and the overhead associated with fat-suppression is avoided. Comparison images acquired using the FS-SSFP method are also presented.

Methods: Experiments were performed on a 3.0T Signa VH/i system (GE Medical Systems, Milwaukee, WI). Non-contrast-enhanced angiograms were acquired using two imaging methods: FS-SSFP and Dixon-SSFP. The experiments were conducted under a protocol approved by our Institutional Review Board, and informed consent was obtained prior to scanning.

The FS-SSFP sequence was used with the following parameters at 3T: TE/TR=1.3/4.2ms, BW=+/-62.5kHz, Matrix = 256x256x56 zero-padded to 512x512x56, FOV=24x24x5.6cm, flip=50°, fat-selective inversion every 14 TR, NSA=2, scan time=6:30min. For comparison, number of signal averages (NSA) was chosen to produce SNR closer to the Dixon-SSFP acquisition

The Dixon-SSFP sequence acquired three SSFP data sets sequentially with a TE increment of 0.60ms to enable the water-fat decomposition. The following imaging parameters were used: TE/TR=1.2,1.8,2.4/4.8ms, BW=+/-62.5kHz, Matrix = 256x256x56 zero-padded to 512x512x56, FOV=24x24x5.6cm, flip=50°, NSA=1, scan time=3:20min. Water and fat images were reconstructed using a 3-point Dixon algorithm with an iterative least-squares approach that permits decomposition of water from fat using arbitrary echo times [9]. Although the TE-increment of 0.6 ms is lower than the optimum of 0.75 ms, a shorter value was chosen to maintain the short TR required to minimize the off-resonance-induced banding associated with SSFP acquisitions. The Dixon-SSFP method is highly SNR efficient, and calculated water-only images have an effective NSA close to 3.

Results: Figure 1 shows maximum intensity projections of non-contrast-enhanced angiograms of the popliteal trifurcation of two healthy volunteers acquired with FS-SSFP (a & c) and Dixon-SSFP (b & d). Fat-water separation was more consistent in the Dixon-SSFP images. While the unsuppressed superficial fat signal (oval) in Fig.1a does not obstruct arterial visualization, the residual signal in the bone marrow in Fig. 1c does reduce arterial conspicuity (oval). The suppression of deep veins was also improved in the Dixon-SSFP images compared to the FS-SSFP results (arrows).

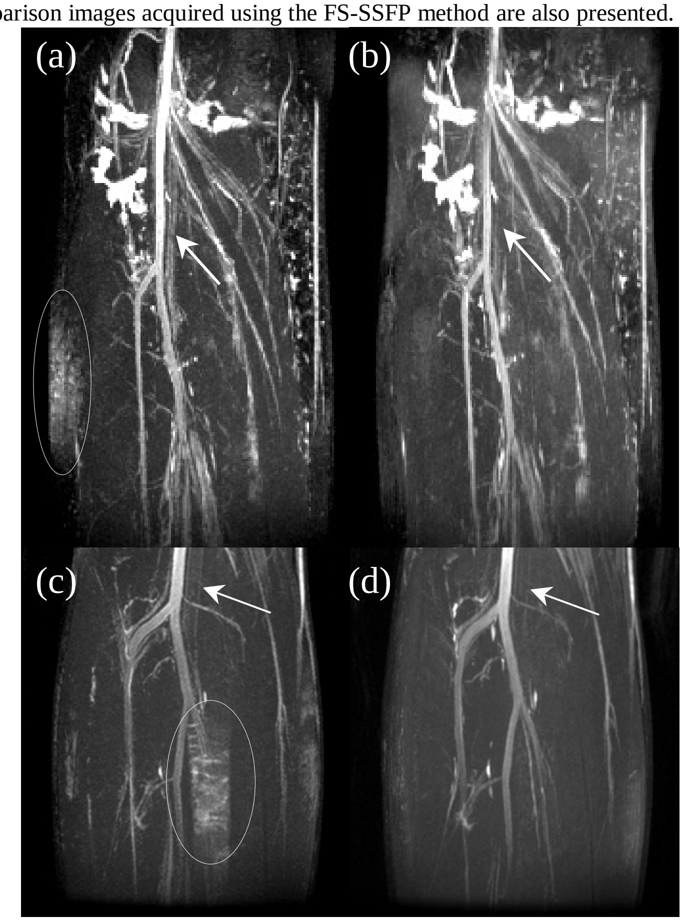

Figure 1: MIP of coronal 3D data sets comparing FS-SSFP (a & c) to Dixon-SSFP (b & d). Note residual signal in subcutaneous fat (a) and bone marrow (c) Also note the reduction in deep venous signal in the Dixon-SSFP results compared to FS-SSFP (arrows). Synovial fluid in the joint also appears bright.

Discussion: The balanced Dixon-SSFP technique demonstrates improved fat suppression and increased time-efficency over balanced SSFP sequence with intermittent fat suppression. In the limited experience to date, the Dixon approach also produces improved arterial-venous contrast. This difference may be explained by the fact that the Dixon-SSFP method acquires data in an uninterupted steady-state. Because the Dixon-SSFP method is SNR efficient and achieves an effective NSA close to three in approximately the same time that the FS-SSFP achieves one average, the Dixon-SSFP method has nearly three times the SNR efficiency.

References:

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