Flow Artifact Suppression in Subtractionless First-Pass Peripheral Angiography Based on Vessel Tree Segmentation

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Target Audience: Physicists and clinicians interested in chemical shift encoding-based water-fat imaging and contrast-enhanced angiography

Purpose: To separate water and fat signals, Dixon methods commonly rely on amplitude and phase differences between composite signals acquired at different echo times. These differences are assumed to result from de- and rephasing of the water and fat signals. However, flow can also cause such differences and can thus induce artifacts[1]. Previously, a suppression of ghost artifacts was demonstrated, as they arise from pulsatile flow at defined distances from the originating vessels in bipolar dual-gradient-echo Dixon imaging[2]. In this work, the effect of flow artifacts inside the vessels is studied, and an extraction of the vessel tree by means of image processing is proposed to facilitate a comprehensive suppression of flow artifacts in subtractionless first-pass peripheral angiography[3].

Methods: There are mainly three flow-related effects occurring inside the vessels that can lead to leakage and swapping artifacts in bipolar dual-gradient-echo Dixon imaging: First, signal amplitude losses with increasing echo time due to intra-voxel dephasing, second, signal amplitude gains from odd to even echoes, and third, signal phase offsets between odd and even echoes, both due to the even echo rephasing effect[2,4]. To consider all of these, the vessel tree was segmented on water images produced with a standard water-fat separation and a ghost artifact suppression[2,5]. The vesselness likelihood was determined for each voxel individually by casting a number of rays isotropically into its neighborhood and computing an intensity-based centricity value, and high totals of voxel-wise vesselness likelihood were combined to build up the vessel tree[6]. Then, in all included voxels, the higher signal amplitude at the two echo times TE_1 and TE_2 was assigned to the water signal, and the fat signal was set to zero. In this way, signal amplitude losses and gains can be compensated, on the assumption that no fat is present in these voxels. Finally, the water-fat separation was repeated in all other voxels, this time without imposing smoothness constraints across vessel boundaries to tolerate potential signal phase offsets.

Flow-related effects inside the vessels and the described approach to their suppression were studied on data from subtractionless first-pass peripheral angiography examinations of 14 patients, which had been imaged with a 3D T_1-weighted spoiled dual-gradient-echo sequence (TE_1/TE_2 = 1.8 ms/3.0 - 3.2 ms) at three stations after injection of 0.1 mmol/kg Gadobutrol (Bayer Healthcare, Berlin, Germany)[3].

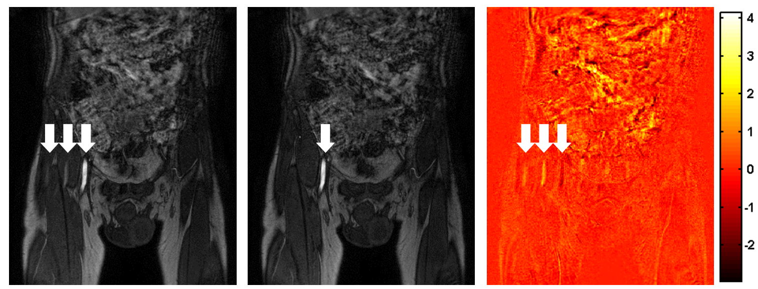

Fig. 1. Source images produced from the first (left) and the second (middle) echo of a bipolar dual-gradient-echo acquisition, and the difference between these source images (right) in arbitrary units.

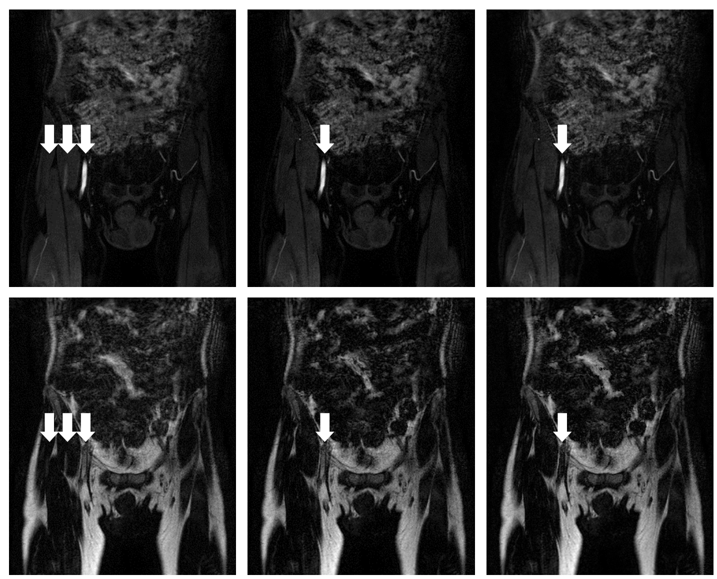

Fig. 2. Water (top) and fat (bottom) images produced from the source images in Fig. 1, without flow artifact suppression (left), with ghost artifact suppression (middle), and with the proposed flow artifact suppression (right).

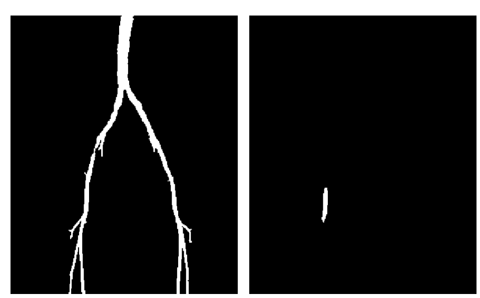

Fig. 3. Coronal maximum intensity projection of the extracted vessel tree (left), on which the proposed flow artifact suppression relies, and included voxels in the slice shown in Figs. 1 and 2 (right).

Results: Flow-induced signal amplitude differences are illustrated in Fig. 1 on a selected slice from the aortoiliac station of one patient. While the ghost artifacts are characterized by higher signal intensity at TE_1, the vessel exhibits higher signal intensity at TE_2. Signal phase differences in the vessel and in surrounding muscles were similar. The ghost artifacts propagate into the water images, and any flow-related signal amplitude differences give rise to leakage artifacts, as seen in Fig. 2. While the ghost artifact suppression leaves the leakage artifact in the vessel unchanged, the proposed approach succeeds in restoring the signal intensity in the water image, based on the vessel tree segmentation shown in Fig. 3.

A dominance of signal amplitude gains over losses from TE_1 to TE_2 was consistently observed inside the vessels, even behind stenoses. Neither abrupt signal phase changes at vessel boundaries nor large signal phase variations inside the vessels were noticed.

Discussion: The results suggest that reversible signal amplitude losses in the first echo, which is not flow-compensated, and not irreversible signal amplitude losses in the second echo might be the primary source of flow artifacts inside the vessels in subtractionless first-pass peripheral angiography. The use of a later, second echo, compared with subtraction first-pass peripheral angiography, would then be non-critical, and the described approach would allow preventing leakage of signal from water into fat images.

References: 1. Eggers H, et al. JMRI 2014; 40:251-268. 2. Eggers H, et al. Proc ISMRM 2013; 310. 3. Leiner T, et al. Eur Radiol 2013; 23:2228-2235. 4. Rahimi MS, et al. MRM 2014; Epub ahead of print. 5. Eggers H, et al. MRM 2011; 65:96-107. 6. Wiemker R, et al. Proc MICCAI 2009; Workshop on Pulmonary Image Analysis 309-314.