Single-Echo Dixon Imaging for First-Pass Contrast-Enhanced Peripheral Angiography without Subtraction

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Introduction

Fat suppression by Dixon methods, which involves the separation of water and fat signals after the acquisition of usually at least two echoes with different echo times, has been explored in non-contrast-enhanced and in steady-state contrast-enhanced angiography [1,2]. Recently, it was also demonstrated in first-pass contrast-enhanced angiography, where it permits eliminating the acquisition of a non-contrast-enhanced reference for fat suppression by subtraction [3]. This application is particularly time-critical and thus demands the use of as few echoes and as short echo times as possible. A flexible dual-echo Dixon method with both echo times shorter than the first in-phase echo time at 1.5 T was therefore employed [4]. In this work, the feasibility of replacing it by a single-echo Dixon method is studied, which promises to further decrease echo and repetition times [5,6].

Methods

Eight patients with suspected peripheral arterial disease were examined on a 1.5 T Ingenia scanner (Philips Healthcare, Best, The Netherlands). After injection of 0.1 mmol/kg Gadobutrol (Bayer Healthcare, Berlin, Germany), source images of the first pass of the contrast agent were acquired in three stations, each with a FOV of 430 x 350 x 150 mm^3, using a T_1-weighted spoiled dual-gradient-echo sequence with a TE_1/TE_2 of 1.8 ms/3.0 - 3.2 ms. The actual spatial resolution increased from 1.3 x 1.3 x 2.8 mm^3 in the first, abdominal station to 1.0 x 1.0 x 1.5 mm^3 in the third, lower leg station. Different coils with about 30 elements per station were automatically selected and supported an 8- to 10-fold acceleration by parallel imaging, leading to scan times between 16 s for the first station and 25 s for the third station.

From these source images, three water or fat-suppressed images were retrospectively separated: one from the first source image acquired at TE_1, one from the second source image acquired at TE_2, and one from both source images [4-6]. The single-echo water images were reconstructed on the assumption that most voxels contain predominantly either water or fat, and all water images were produced using the same algorithm for the estimation and correction of phase errors. For visualization, maximum intensity projections were calculated along the AP direction and were stitched to obtain a virtual FOV of 1210 mm in FH direction.

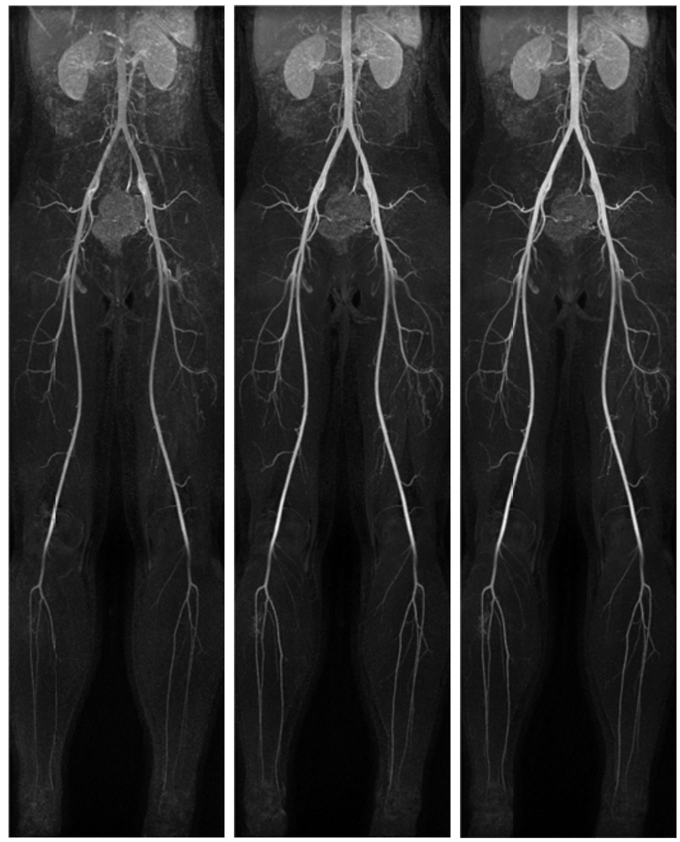

Fig. 1. Maximum intensity projections of water images produced from the first echo (left), the second echo (middle), and both echoes (right) of a three-station dual-echo acquisition, cropped in RL direction.

Results

Fig. 1 shows the results for one patient. The homogeneity and extent of fat suppression is generally good in all three cases. Artifacts attributable to the stringent assumption made by the single-echo Dixon method are mostly subtle. Poorer SNR reduces the discernability of vessels in particular in the first single-echo case, which also suffers from ghosting artifacts in the abdomen. Fig. 2 shows details of the results for another patient with occlusions in both legs. The collateralization is depicted best in the dual-echo case and worst in the first single-echo case. Similar observations were made in the other patients, for which the separation of water and fat signals was found to be less stable overall in the single-echo cases.

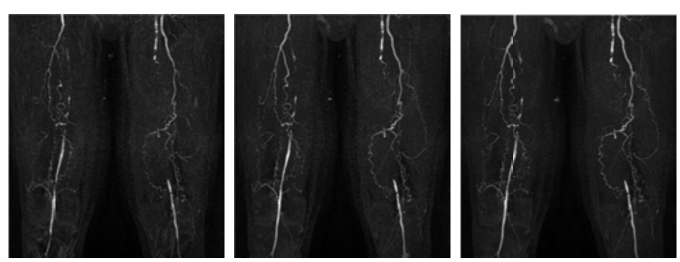

Fig. 2. Details of maximum intensity projections of water images produced from the first echo (left), the second echo (middle), and both echoes (right) of a dual-echo acquisition.

Discussion

In the dual-gradient-echo sequence applied in this work, the TEs represent a compromise between speed and SNR. The effective NSA at 1.5 T is given by $\sin^2(360°\cdot TE/4.6\,ms)$ in the two single-echo cases and by $1-\cos(360°\cdot(TE_2-TE_1)/4.6\,ms)$ in the dual-echo case, amounting to 0.4, 0.7 - 0.9, and 1.1, respectively [4,7]. Obviously, the first single-echo case would benefit from a shorter TE, as a tailored single-gradient-echo sequence would provide it. The apparent sensitivity to flow artifacts may demand the use of flow compensation, however, leading to a longer TE and thus even poorer SNR. By contrast, the second single-echo and the dual-echo case benefit from the inherent gradient moment nulling for the even echoes in multi-gradient-echo trains.

Conclusions

The feasibility of single-echo Dixon imaging for fat suppression in first-pass contrast-enhanced peripheral angiography without subtraction was demonstrated. Initial experiments at 1.5 T indicate substantial potential for reducing scan time or enhancing spatial resolution, but also higher sensitivity to flow and swapping artifacts compared to dual-echo Dixon imaging. Moreover, the choice of echo time proves more critical to attain an adequate SNR. Depending on the spatial resolution and field strength, this may restrict the acceleration achievable with single-echo Dixon imaging in practice.

References

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