Adjustable Suppression of Water Signal in the Background in Subtractionless First-Pass Peripheral Angiography with Dual-Echo Dixon Imaging

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Introduction

Recently, a subtractionless approach to first-pass peripheral angiography based on dual-echo Dixon imaging has been proposed as an alternative to the established subtraction approach [1,2]. It has been demonstrated to provide higher signal-to-noise ratios and to reduce motion artifacts by eliminating the subtraction. It involves chemical shift encoding in the acquisition to suppress the fat signal, the major component of the background signal, in the reconstruction. Unlike the subtraction approach, which ideally removes both water and fat signal from the background, it preserves the minor component of the background signal, the water signal. This leads to a different appearance in particular of the maximum intensity projections (MIPs) calculated for the visualization of the vasculature. In this work, an image processing method is suggested for the separation of the water signal in the background from the enhanced water signal in the vessels and is evaluated on clinical examples.

Methods

The proposed method relies on signal intensity and structure size differences for the separation. It assumes that either the signal intensity in the vessels substantially exceeds the signal intensity in the background or the water signal in the background mainly stems from homogeneous tissue that is large compared with the cross section of the vessels. First, it determines the location of the maximum signal intensity for each pixel in the MIP to be calculated. Then, it performs a histogram analysis to mask out large vessels with high signal intensity. If the location of the maximum signal intensity remains unaffected by the last step, this location is supposed to be within a vessel, and the edges of this vessel are determined by thresholding. Additionally, the distance of these edges to the location of the maximum signal intensity is limited by a specified maximum vessel size. All voxels within this alleged vessel are excluded from the following step. Finally, a local median filtering is applied to the remaining voxels along the projection direction, and the maximum signal intensity is taken as water signal in the background.

Patients were imaged before and after administration of 0.1 mmol/kg Gadobutrol (Bayer Healthcare, Berlin, Germany) on a 1.5 T Ingenia scanner (Philips Healthcare, Best, The Netherlands) with a 3D T_1-weighted dual-gradient-echo sequence (TE_1/TE_2 = 1.8 ms/ 3.0 - 3.2 ms) at three stations [1]. Resulting source images were processed with mDIXON to obtain water-only images [3], and coronal MIPs were calculated from these water-only images for the visualization of the vasculature, both without and with the described additional background suppression.

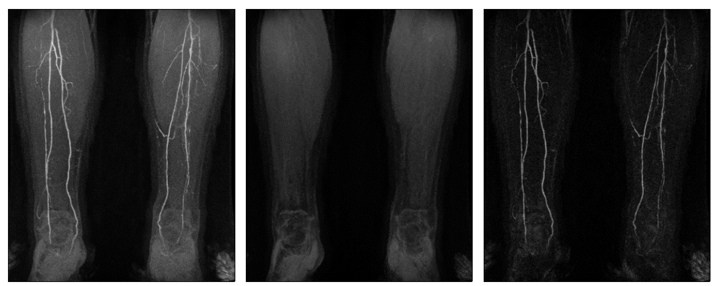

Fig. 1. Coronal maximum intensity projection of three-dimensional water images obtained with subtractionless angiography (left), background extracted from water images with the proposed method (middle), and their difference (right).

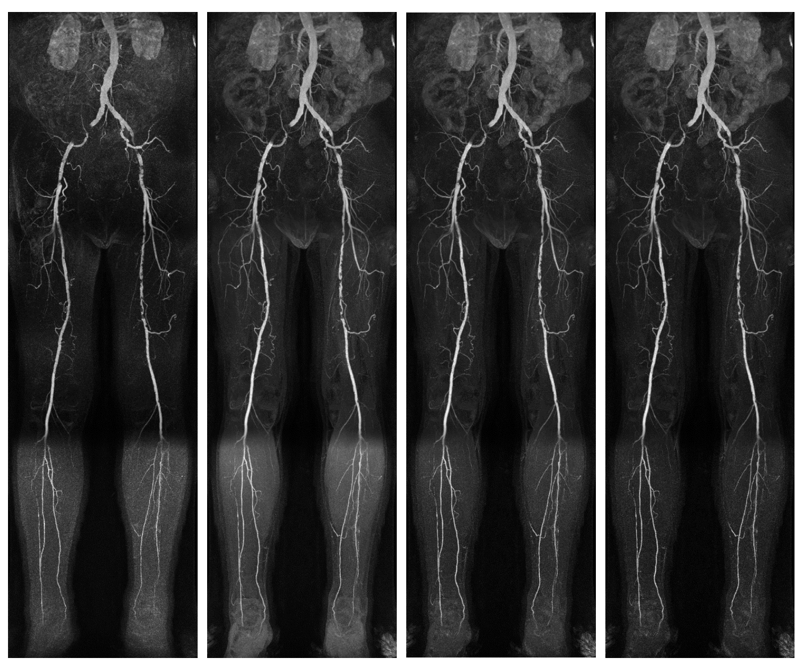

Fig. 2. Stitched coronal maximum intensity projections of images obtained with subtraction angiography (left) and water images obtained with subtractionless angiography (others), the latter once without and twice with the described additional background suppression, using a weaker and a stronger setting, respectively.

Results

The proposed method is illustrated in Fig. 1 on images from the lower leg station of one patient. The non-enhanced water signal in the background above the feet mainly originates from the calves. It is well separated from the enhanced water signal in the vessels by the proposed method, as also the difference image shows. An adjustable suppression of the water signal in the background is demonstrated in Fig. 2 on images from all three stations of the same patient. The stitched MIP of the subtraction images is shown for reference, in which the background signal is primarily due to noise, and only secondarily due to motion in this case. The stitched MIP of the water images exhibits higher background signal, in particular in the lower legs. This is noticeably reduced by the application of the proposed method, of which two examples with different settings are given.

Discussion

The subtractionless approach to first-pass peripheral angiography provides only a partial suppression of background signal, independent of potential motion of the patient. While some consider this as an advantage, because the visibility of anatomical landmarks is preserved, it may hamper the acceptance of the subtractionless approach by others. The proposed method permits tailoring the extent of background signal remaining in the MIPs especially in the legs and the pelvis to individual preferences. However, it does not suppress more complex structures in the abdomen, like the intestine. Due to the local median filtering, it keeps the loss in signal-to-noise ratio minimal.

References

1. Ho KY, et al. Radiology 1998; 206:683-692. 2. Leiner T, et al. Proc ISMRM 2012; 525. 3. Eggers H, et al. Magn Reson Med 2011; 65:96-107.