BLOOD VESSEL CONTRAST ENHANCEMENT USING PHASE CORRECTED REAL IMAGING IN FLOW-SENSITIVE BLACK BLOOD IMAGING

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Introduction

A flow-sensitive black-blood imaging (FSBB) technique was proposed, where small motion probing gradients (MPG) of b-factor=2~4 [sec/mm^2] were combined with a 3D gradient-echo (GRE) sequence [1]. The FSBB technique was demonstrated to enhance slow flow vessels, such as collateral vessels [2], perforating veins [3], vascular malformations [4]. Simple magnitude images provided sufficient vessel to background contrast since MPG introduces sufficient dephasing due to intra-voxel incoherent motion (IVIM). However, in some slow flow vessels where the intra-voxel coherent motion (IVCM) flow effect is relatively greater than the IVIM effect, magnitude images did not provide adequate vessel contrast or sometimes introduced wraparound artifacts when the absolute value of signal phase in the vessel is greater than $\pi/2$. The purpose of this study was to enhance blood to background contrast and to correct the wraparound artifacts in magnitude-based FSBB imaging.

Methods

As shown in **Fig.1**, signal phase in blood vessels in GRE-based FSBB is a summation of components due to flow and background, and the background signal phase is spatially dependent. The correction process was as follows: First, the background phase was separated by subtracting low-frequency phase components from the original, which was widely used in a phase contrast MRA or a partial-Fourier imaging [5]; second, the real part was obtained as:

$$I_{cor} = real[S_{cor}] = real[S_{orig} \cdot S_{low}^{*} / |S_{low}|]$$

where S_{orig} is an original complex signal, S_{low} is a low-pass filtered complex signal obtained by $S_{low}=H_{low}[S_{orig}]$ using a 3D low-pass filter, H_{low}, and S_{low}* is a complex conjugate of S_{low}. The H_{low} used here was a linear Gaussian type in 3D k-space and the FWHM was 40 % of the maximum sampling frequency, where the degree of smoothing was experimentally decided to enhance vessels while suppressing background phase. If the background signal phase can be eliminated, useful images of the real part of complex signal becomes available. With these real-part images, vessel to background contrast, C=I_{cor}(vessel)-I_{cor}(back) after this correction is always negatively greater than the C for the magnitude signal in FSBB. Imaging was performed on a 1.5-T whole-body imager (EXCELART Vantage^{TM}, Toshiba Medical Systems Corp.). Imaging conditions were: 3D-GRE sequence (FE3D) with TR/TE/FA=32ms/20ms/20deg and flow-dephasing gradients of b=2 s/mm^2, acquisition voxel size of 0.9x0.7x0.9mm^3 interpolated to 0.45x0.35x0.45mm^3, and parallel imaging with a reduction factor of 2. Minimum intensity projection (mIP) images and the vessel profiles were compared before and after the correction.

Results and Discussions

Wraparound artifacts which appeared on blood vessels in the original magnitude image were corrected and thus the vessel-background contrast was enhanced after the proposed correction (**Fig. 2**). Vessel phase measurements based on the technique of subtracting low-frequency components are usually underestimated as the vessel size becomes larger. However, vessel-background contrasts became greater in almost vessels by this correction compared with those in the magnitude image. If more contrast enhancement is required, it is possible to use a nonlinear process to generate the phase map, giving phase closer to π while background phase is kept closer to zero. This correction is particularly useful for slow-flow vessels and when the surrounding background signal is smaller, such as in this example. This technique is also likely to be useful for enhancing blood-vessels in a hybrid MRA technique in combination with TOF and FSBB [6].

References

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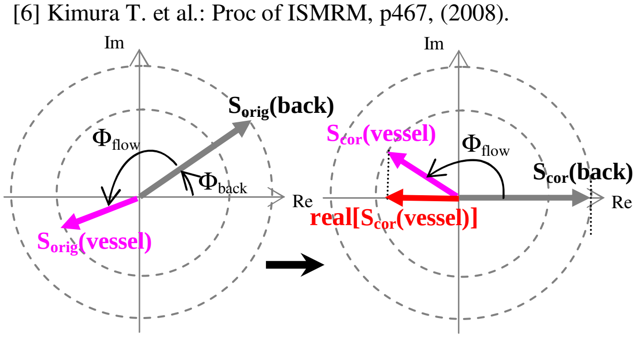

Fig.1. Schematic for vessel and background complex signals before and after background phase correction.

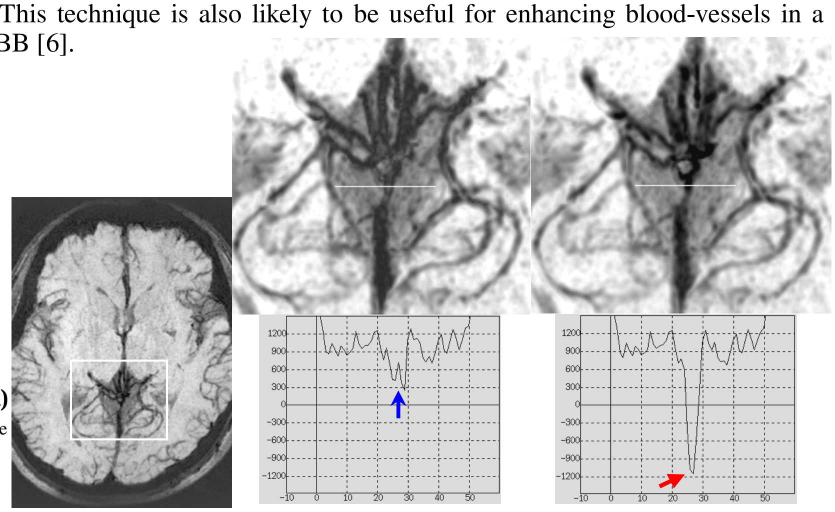

Fig. 2. FSBB mIPed images and the profiles on blood vessels before (left) and after (right) phase correction. Wraparound artifacts (blue arrow) in blood vessels were corrected and the vessel-background contrast was enhanced after the proposed correction (red arrow).