PHASE-ENHANCEMENT TECHNIQUE FOR A HYBRID-OF-OPPOSITE-CONTRAST MR ANGIOGRAPHY

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Introduction: A Flow-sensitive black-blood (FSBB) technique employing to 3D gradient echo (GRE) with motion-probing-gradient [1], and a MRA technique named Hybrid-of-opposite-contrast (HOP) MR angiography combining TOF and FSBB using dual-echo 3D-GRE [2] were proposed. In addition, basic idea for correcting wraparound signal in vessels using phase-corrected real signal in FSBB was also proposed [3]. The purpose of this study was to propose and assess an advanced technique of image processing using phase and magnitude signal for further enhancing blood-to-background contrast for HOP sequence.

Methods: A sequence of dual-echo 3D-GRE with flow-dephasing on both echoes and an image processing technique for phase-enhancement were combined. The enhancement process was as follows: First, the background phase was separated by subtracting low-frequency phase from the original [3,4]; second, the normalized real part of corrected complex signal, $\cos(\Phi_{cor})$, was obtained as:

$$\cos(\Phi_{cor}) = real[(S_{orig}/|S_{orig}|)\cdot(S_{low}{}^*/|S_{low}|)] \quad (1)$$

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. A cosine function filters (**Fig. 1**) for white blood, H_W (**a**) and FSBB, H_B (**b**) were respectively defined so that vessels were enhanced white and black as:

$$H_W = 2 - M^n \text{ and } H_B = 2(M^n - 0.5) \text{ where } M = (1 + \cos(\Phi_{cor}))/2\,,$$

and n is a parameter to control enhancing strength, H_B was applied only to negative phase (asymmetric type) for reducing susceptibility artifacts. A phase-enhanced HOP image is finally obtained by

$$I_{cor} = H_W \cdot |S_W| - H_B \cdot |S_B| \quad (3).$$

Imaging was performed on a 1.5-T whole-body imager (EXCELART Vantage[TM], Toshiba Medical Systems). Imaging conditions were 3D-GRE sequence (FE3D) with TR=30ms, TE=3.4ms with 0th GMN for 1st echo, 23.8ms with b-value=2s/mm^{2} for 2nd echo, FA=20deg, bandwidth=31.2kHz/FOV, FOV=20cm, slice thickness=1mm, acquisition matrix of 256x256x40 interpolated to 512x512x80 after zero-filling outside of 70% partial echo data, and parallel imaging with a reduction factor of 2. Here magnitude images before phase-enhancement were processed with standard filter for TOF or FSBB alone, while spatially high-pass filters in Ref.[2] were applied to 2 images for HOP. Maximum or minimum intensity projection (MIP or mIP) images before and after phase-enhancement were compared for normal volunteer brain obtained after obtaining informed consent.

Fig.1 Shape of cosine filters, H_w for white blood (a), and H_B for black-blood (b) shown as a strength parameter of n=1 to 16.

Results and Discussion: Volunteer images and the profiles were shown in **Fig. 2**. Smaller vessels were further delineated by phase-enhancement technique in all 3 kinds of MRA. FSBB could provide negative vessel signals and thus those vessels were depicted without interference by lower signals of CSF, air or skull even using miP. The enhancing strength parameter, n was depended on the SNR and TE of original images; n=8 was optimum here, but too high n introduced background artifacts due to fat or susceptibility artifacts. The 2nd TE of HOP sequence is likely to be shortened while keeping or enhancing blood-to-background contrast by combing this technique with reducing b-value for 2nd echo (FSBB) in addition to 0th order gradient moment for 1st echo (TOF). In conclusion, our proposed phase-enhanced technique is a very promising technique to improve blood-to-background contrasts on all 3 kinds of MRA for HOP sequence without extra acquisition, though further optimization and clinical assessments are required.

References
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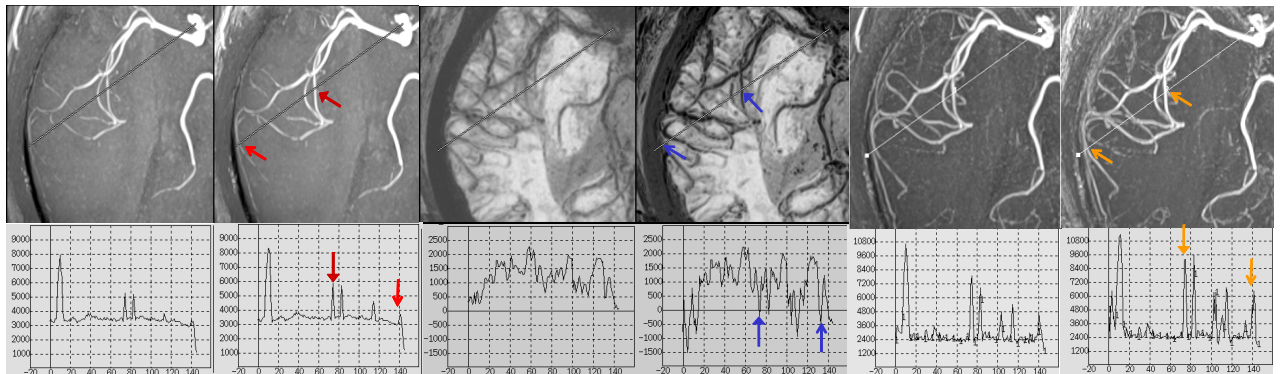 JMRI12:661-670.
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Fig. 2. Volunteer images and profiles of TOF (left), FSBB（middle）, and HOP (right) –MRA; respectively, the left is pre- and the right is post- enhancement. Note that small vessels (arrows) in all 3 kinds of images were enhanced by phase-enhanced processing. Enhancement strength parameter of n=8 was commonly used. Note that the left side of each pr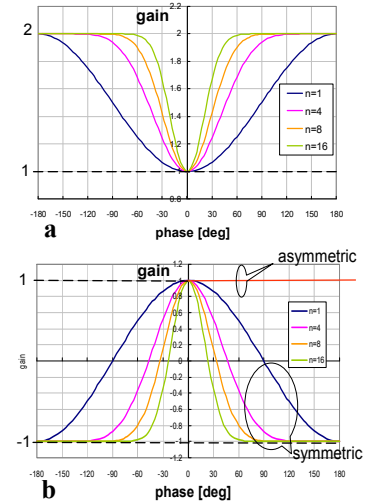ofile corresponds to the side of MCA 1st branch.