Peripheral MR Angiography using Fourier Velocity Encoding and Dynamic Reconstruction

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Target Audience

MR engineers who are interested in angiography.

Introduction

Recently, non-contrast-enhanced MR angiography (NCE-MRA) techniques have been proposed for the increased concern of nephrogenic systemic fibrosis (NSF) caused by gadolinium-based contrast agents.1 NCE-MRA techniques such as time-of-flights (TOF) and phase contrast (PC) imaging generate flow dependent signal by the fact that blood is moving relative to other tissues. However, these techniques need long imaging time and are less sensitive to slow blood flow. Thus, the use of TOF and PC techniques in peripheral region is limited. Recently, Quiescent-interval single-shot (QISS) MRA technique was developed to resolve these problems. QISS uses saturation RF pulse and one-shot balanced SSFP technique to overcome these issues.2 However, QISS technique needs multiple RF pulses to saturate background and fat signal and these multiple RF pulses can cause the high SAR. In this work, we propose a new MRA technique using the Fourier velocity encoding and dynamic reconstruction, which could eliminate background signals without saturation pulses.

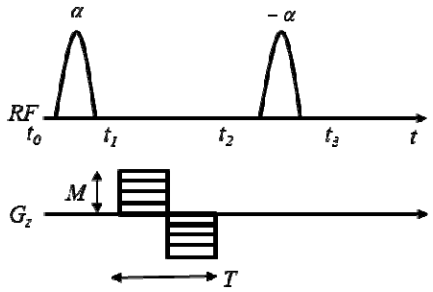

Figure 1. Fourier velocity encoding based angiogram sequence diagram.

Methods

We used α and $-\alpha$ pulse train and acquired multiple images with selected VENCs. The details of pulse sequence are shown in Fig. 1. In the proposed signal acquisition scheme, the magnitude and phase of signal are determined by the phase change of transverse signal between the first and second RF pulses and the phase change (ϕ) can be defined as follows:

$$\phi = \gamma G(T/2)^2 v + \phi_0 \tag{1}$$

where γ is the gyromagnetic ratio, G and T are the magnitude and duration of velocity encoding gradient, respectively, v is the velocity of flow and ϕ_0 is the phase change caused by field inhomogeneity. Consider a magnetization vector $\vec{M}$ at equilibrium with a magnitude of M_0 is [M_x, M_y, M_z]=[0, 0, M_0]. Then the magnetization vector after second RF pulse at t_3 in Fig.1 can be represented as follows:

$$\left[M_x, M_y, M_z\right] = \left[M_0(\sin\alpha\cos\alpha\cos\phi - \sin\alpha\cos\alpha), M_0\sin\alpha\sin\phi, M_0\sin^2\alpha\cos\phi + \cos^2\alpha\right] \tag{2}$$

where α is the flip angle of RF pulse. In the eq. (2), signals from blood signal is varied by the magnitude of flow encoding gradient (M) and signal of the static background including fat is not changed by flow encoding gradient. The simulation result is shown in Fig. 2. To eliminate background signals in the proposed method, we acquired highly under-sampled signals for selected VENCs and reconstructed images using k-t FOCUSS.[2] Then, Fourier transform is performed along VENC axis as follows:

$$I(x, y, f) = \Im(I_{recon}(x, y, VENC)) \tag{3}$$

where I_{recon} is the reconstructed image for each VENC and $\Im$ is the Fourier transform along the VENC axis. As the signal from the static background even with field inhomogeneity is not changed by VENC, $I(x, y, 0)$ contains all the signals from the static background. Thus, the MR signals related with blood flow correspond to the high frequency signal of $f \neq 0$. Thus, the angiography (I_{Angio}) is constructed as follows:

$$I_{Angio}(x, y) = \sum_{f \neq 0} I(x, y, f). \tag{4}$$

Results

In-vivo experiments were performed at a 3.0T MRI system (Siemens Magnetom Verio, Erlagen, Germany) with a matrix coil to verify the proposed angiography technique. The angiogram was acquired using the following parameters: field-of-view (FOV) = 190 × 380 mm^2, slice thickness = 2.5 mm, flip angle = 50°, and TR/TE = 24/11 ms. Three groups of 50 slices were acquired to span the peripheral arteries. As shown in Fig. 3, the proposed method well reconstructed peripheral angiography without saturation pulses.

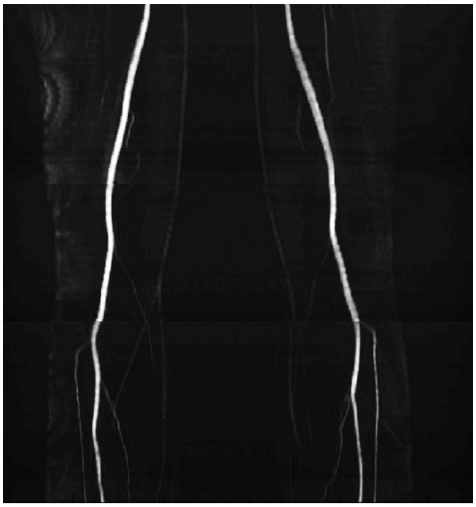

Figure 3. Peripheral angiogram from the proposed method

Conclusions

In this paper, new MRA technique using Fourier velocity encoding was proposed, which could produce peripheral angiogram without saturation RF pules.

References

1. HS Thomsen, Eur Radiol 2006;16:2619-2621, 2. RR Edelman et al., MRM 2010;63:951-958 3. Jung et al., MRM 2009, 61:103-116

Acknowledgement

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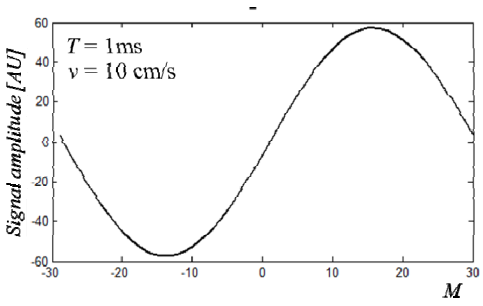

Figure 2. Simulated MR signal with respect to gradient strength (M) in the proposed method