Flow Preparation Pulse for Abdominal Non-Contrast-Enhanced MRA

M. Miyoshi[1], T. Tsukamoto[1]
[1]GE Yokogawa Medical Systems, Hino, Tokyo, Japan

Abstract

Steady State Free Precession (SSFP) yields high blood signal image in short scanning time and it enables Non-Contrast-Enhanced MR Angiography (NCE-MRA) in abdomen. However, SSFP produces bright signal not only in artery but also in vein or stationary fluids. We propose new Flow Preparation (Flow Prep) pulse to distinguish artery from vein and stationary fluids. This technique was developed based on bipolar velocity encoding (VENC) used in Phase Contrast Angiography. Phantom examination showed that signal intensity of the Flow Prep matched with theoretical values. The Flow Prep enhanced the contrast of artery in volunteer scans.

Introduction

SSFP can be used for abdominal NCE-MRA because of its high artery signal. However, vein and stationary fluid suppression is required. Yamashita et al. tried combination of inversion recovery and image subtraction [1]. They made subtraction image between images with non-selective IR pulse and with selective IR pulse and fast in-flow artery was depicted. However, subtraction method is sensitive to motion and it doubles scanning time. We propose Flow Prep in which contrast depends on flow velocity. This method doesn't use image subtraction.

Methods

Pulse sequence chart of the Flow Prep is shown in figure 1. Non-selective RF pulses sandwich the VENC gradients. As the RF pulse sequence is base on CPMG, it's not sensitive to magnetic field inhomogeneity and chemical shift. Magnetization vectors are also illustrated in figure 1. Stationary magnetization (black arrow) is not rotated with the VENC pulse (4) and it is flipped to My axis (6). On the other hand, flow magnetization (red arrow) is rotated by the VENC and is flipped back to Mz axis. Then a dephaser gradient pulse crushes transverse magnetization (7). As a result, longitudinal signal intensity after the Flow Prep is a function of the flow velocity (Eq. 1).

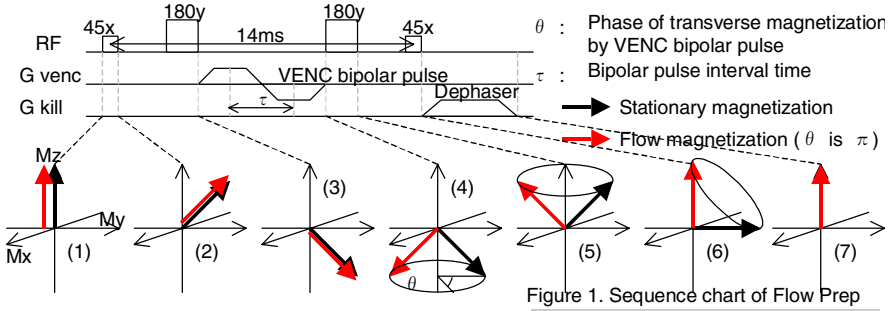

Figure 1. Sequence chart of Flow Prep

$signal = M0 \times (1 - \cos(\theta))/2$; where τ is bipolar pulse time interval (2ms) and

$\theta = 2\pi \times (\text{Gyromagnetic ratio}) \times (\text{velocity}) \times \tau \times (\text{VENC gradient area})$. (Eq. 1)

We measured laminar flow with NiCl flow phantom with the Flow Prep. The flow velocity range was between 93 and 1390 mm/s that was measured with 2D Phase Contrast. The VENC gradient area was fixed so that θ in Eq. 1 became π for 1000 mm/s flow velocity. Data was acquired with 3D SSFP after the Flow Prep. Linear RF ramp up was in 5 TRs. Phase encodings (ky) were acquired in centric order with one Flow Prep. After waiting 500 ms for T1 relaxation and in-flow of fresh fluid, next kz line was acquired. Parallel imaging was used to reduce scanning time. TR/TE/Flip Angle of SSFP was 3.7ms/1.9ms/90deg.

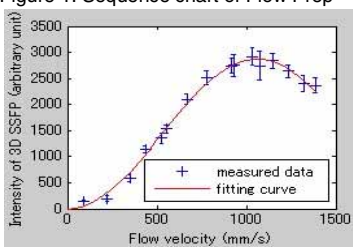

Figure 2. Flow Prep signal intensity

In the volunteer scans, the flow velocity of artery changes in cardiac cycle and in the portion of the vessel. We measured it before volunteer scans with 2D gated Phase Contrast. The flow velocity and the trigger delay of the volunteer in figure 3 were 633 mm/s and 205 ms at abdominal aorta, 709 mm/s and 233 ms at common iliac artery, respectively. We chose 650mm/s and 233 ms for the Flow Prep. Direction of the Flow Prep VENC gradient was S/I. So R/L, A/P and slow flow signals were suppressed. However, by adding 100ms-waiting time after the Flow Prep, fast S/I flow signals flowed in R/L, A/P or small vessels. In this waiting time, longitudinal magnetizations of short T1 tissues (especially Fat) relaxed and they became background. Spectral IR was applied to suppress Fat signal just before the data acquisition. Respiratory Trigger was used to reduce motion artifact. 2 kz lines were acquired in one breath. Voxel size was isotropic 1.6mm. TR/TE/Flip Angle of SSFP was 4.1ms/2.0ms/120deg. Total scanning time was 140 s.

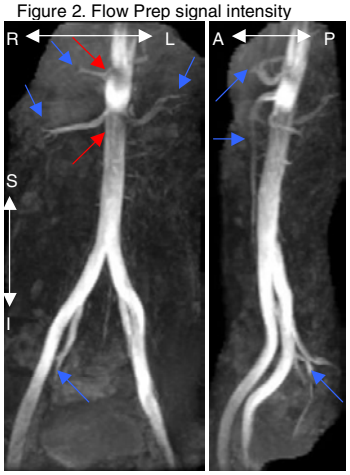

Figure 3. Volunteer image

Results

Result of laminar flow phantom is shown in figure 2. Measured intensity is plotted in blue and red line is its least mean square fit. Peak of the fitting curve is found at the flow velocity of 1059 mm/s. This means the Flow Prep exhibited 5.9% flow velocity difference compared to Phase Contrast. The result of volunteer scans is in figure 3. R/L, A/P and small vessels (blue) are depicted. However, some portions of aorta are weakened (red).

Discussion and Conclusion

Phantom examination showed that the results of the Flow Prep matched theoretical values. Trigger delay, flow velocity and waiting time were critical parameters in volunteer scans. Although the Flow Prep modulates phase only for S/I flow, 3 directional flows were depicted because of in-flow effect during the waiting time. Vein and stationary fluids were well suppressed.

The Flow Prep increased the contrast of artery and it was effective for Abdominal NCE-MRA.

Reference [1] Y. Yamashita et al. ISMRM 13 (2005), 1715.