Flow-Preparation and Flow-Saturation-Preparation pulses for abdominal Non-Contrast-Agent MR Angiography

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Abstract

Flow-Preparation pulse (Flow-Prep) can separate arterial signals from venous and stationary fluid signals [1,2]. This method is applied to aorta in this paper. We also present Flow-Saturation-Preparation pulse (Flow-Sat-Prep), which can saturate multi directional flows. Subtraction between Flow-Sat-Prep and control images can distinguish arterial signals. Aortic arch is depicted in volunteer studies.

Introduction

Non-Contrast-Agent MR Angiography (MRA) is an emerging technology especially in lower extremity. One of these methods is based on ECG-gated 3D FSE-IR [3]. Arterial signals change in different cardiac phase in FSE and they are depicted with image subtraction between two different cardiac phases. However, because of motion artifacts of FSE images, the FSE-based method is not easily applied to abdominal region. Although Steady State Free Precession (SSFP) is often used for abdominal MRA instead of FSE, arterial and venous signals are not separated. To increase the contrast of arterial signals of SSFP, Flow-Prep was developed [2]. The Flow-Prep utilizes single directional Velocity ENCoding (VENC) gradients in the CPMG pulse sequence. The Flow-Sat-Prep saturates arterial signals with VENC and crusher gradients. Arterial and venous signal separation in SSFP becomes available with image subtraction between the Flow-Sat-Prep and control images.

Methods

Pulse sequence chart of new Flow-Prep is shown in Fig.1. Non-selective RF pulses sandwich VENC gradients. In this paper, refocus RF pulses of Flow-Prep is modified from CPMG type to MLEV-4 type because MLEV-4 is generally less sensitive to magnetic field and RF inhomogeneity than CPMG.

Flow-Sat-Prep, in which VENC and crusher gradients saturate multi dimensional flows, is shown in Fig.2. Flow void occurs along G-crush axis because the crusher gradients give different first order moment between stimulated echoes and spin echoes of the flow signals. The ratio of the flow void, which depends on flip angle of two refocus RF pulses (120y and –120y) and the area of crusher gradients, is simulated. The effect of G-venc gradients is similar to Flow-Prep. Control images without Flow-Sat-Prep is required for image subtraction. To match the contrast of the backgrounds, preparation pulse for the control images should be simple MLEV-4 (Fig.3).

In the volunteer test, peak flow velocity along G-venc axis and trigger delay time were measured with Gated Phase Contrast previously. Flow velocity along G-crush axis was assumed to be 30 cm/s. Preparation pulse was applied in systolic phase (Fig.4). 3D SSFP data acquisition was applied after around 200ms waiting time from Preparation pulse. T2-Prep and Spectral IR were applied to suppress background signals. Respiratory Trigger was used to reduce motion artifact. TR/TE/Flip Angle of SSFP was 3.6ms/1.8ms/90deg. Slice thickness is 2mm. Scanning time was 140s and 280s for Flow-Prep and Flow-Sat-Prep, respectively.

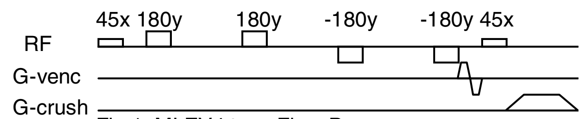

Fig.1. MLEV4 type Flow-Prep

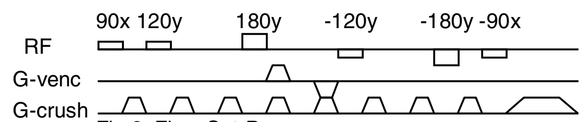

Fig.2. Flow-Sat-Prep

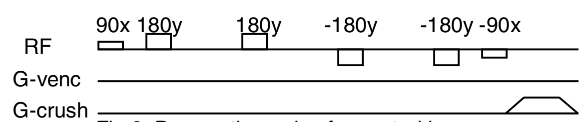

Fig.3. Preparation pulse for control images

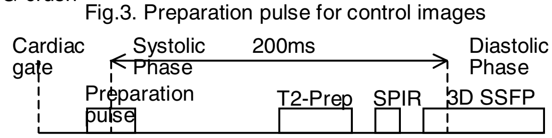

Fig.4. Pulse Sequence Chart

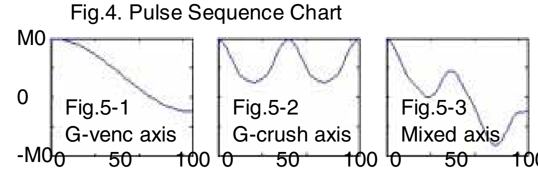

Fig.5 Signal phase and signal intensity.
(Transverse: Flow velocity (cm/s))

Results

The simulation results of the signal intensities after Flow-Sat-Prep are shown in Fig.5. When the laminar flow velocity was 100 cm/s, phases of the flow signals induced by VENC or crusher gradients were assumed to be 180 degree. T2 decay is neglected because the time between first and last RF pulse (26ms) is much shorter than T2 of the arteries. The flow signals along G-venc axis are negative at 100 cm/s (Fig.5-1). The flow signals along G-crush axis have 3 peaks (Fig.5-2). Signal intensity of the flow along G-venc and G-crush mixed axis is in Fig.5-3.

Maximum Intensity Projection (MIP) of volunteer image with Flow-Prep is shown in Fig.6-1. Fig.6-2 is a MIP of control image. Fig.6-3 is a MIP of the subtraction images between control and Flow-Sat-Prep images. Aortic arch is more uniformly depicted with Flow-Sat-Prep (Fig.6-3) than with Flow-Prep because Flow-Sat-Prep is more robust to multi directional flow. On the other hand, small arteries like renal and superior mesenteric arteries are in the same level. However, the scanning time of Flow-Sat-Prep images is twice as long as Flow-Prep because control images need to be acquired with Flow-Sat-Prep.

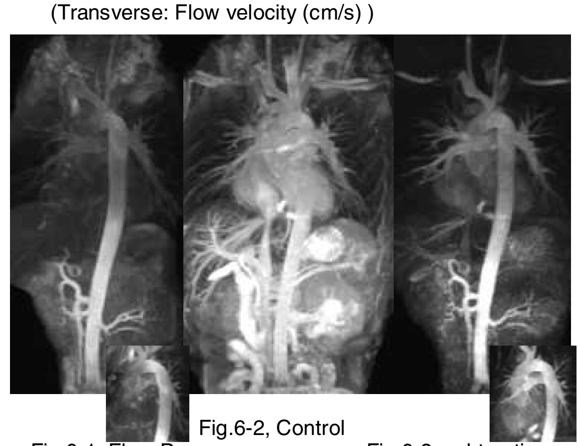
Fig.6-1, Flow-Prep Fig.6-2, Control Fig.6-3, subtraction

Discussion and Conclusion

In Fig.5-2 and 5-3, the 2nd and 3rd intensity peaks can be nearer to 0 because flows are not laminar in the blood vessels and peaks can blur.

The Flow-Prep is effective for small arteries and Flow-Sat-Prep is effective for aortic arch. These are effective for MRA in abdominal region.

Reference [1] Korosec F. R. et al., MRM 30:704-714, 1993.

[2] Miyoshi M. et al., In Proceedings of ISMRM 2006, 1932.

[3] Miyazaki M. et al., Radiology 227:890-896, 2003.