T1 insensitive background saturation by two inversion pulses for Flow-Prep Non-Contrast-Agent MR Angiography

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Purpose

Flow-Preparation-pulse (Flow-Prep) is a preparation pulse that enhances flow signal and suppresses stationary signal. To avoid T1 relaxation between the Flow-Prep and the data acquisition, we applied two inversion recovery (IR) pulses, which enabled T1 insensitive background suppression and preserved high contrast between flow and stationary signals.

Introduction

Flow-Prep is a set of preparation pulses that contains RF and Velocity ENCoding Gradients (VENC) (Fig 1-1) [1,2]. This technique gives flow-velocity dependent signal intensity and saturates stationary magnetizations. To depict renal artery, the Flow-Prep suppresses stationary signals and tags the flow signal in the aorta, which flows into the renal artery in following 300ms waiting time, and then MR signal is acquired with 3D SSFP (Fig. 1-2). However, the T1 relaxation of fat, kidney and intestinal contents increases unwanted background signals. Although Spectral IR (SPIR) can suppress the fat signal and T2-Prep can suppress the kidney signal, they cannot suppress the short-T1 intestinal contents. SPIR and T2-Prep increase patient heating Specific Absorption Rate (SAR). Image subtraction can improve background suppression [3] but it doubles scanning time and is sensitive to body motion, which causes misregistration.

T1 of blood or intestinal contents are around 1200 or 200ms, respectively. Short Tau Inversion Recovery (STIR) with single IR pulse is a good method to suppress short-T1 intestinal contents. However, IR pulse inverts the flow signal to negative intensity and long T1 recovery time (>2000ms) is required before next data acquisition. Dixon W. T. et al. reported another method [4]. They suppressed the stationary signal with Spatial Saturation pulse. Then they applied two or multiple IR pulses to keep the stationary signal near to zero and waited the in-flow of the arterial signal. However, long in-flow waiting time is required to depict the slow flow signal.

We present the Flow-Prep followed by two IR pulses. The Flow-Prep enhances the flow signal and suppresses the stationary signal. Two IR pulses keep the stationary signal near to zero and contrast between flow and stationary signals is preserved until the start of the data acquisition. This does not require T2-Prep, SPIR, and subtraction. It does not also require long T1 recovery time and long in-flow waiting time.

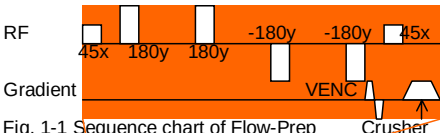
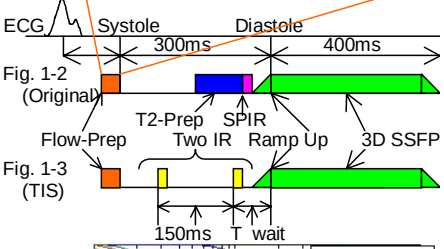


Fig. 1-1 Sequence chart of Flow-Prep



Methods

Intensity of the stationary signal was simulated with/without the two IR pulses. Sequence chart is in Fig. 1-3. Signal intensity after the Flow-Prep was assumed to be 0. Time between the Flow-Prep and the data acquisition was fixed to 300ms. Time between first and second IR pulse was fixed to 150ms. Time between second IR and data acquisition (T_wait) was modified for 75, 60 and 45ms. T2-Prep, SPIR, SSFP ramp up were neglected. IR pulse width was assumed to be 0 (delta function). Simple T1 relaxation with/without two IR pulses were simulated. T1 was from 10 to 2000ms.

We compared 3 methods in phantom and volunteer studies. “Simple SSFP” means a simple 3D SSFP without any preparation pulses. “Original method” means 3D SSFP with Flow-Prep, T2-Prep and SPIR (Fig. 1-2). “TIS (T1 Insensitive Saturation) method” means 3D SSFP with Flow-Prep and two IR pulses (Fig. 1-3).

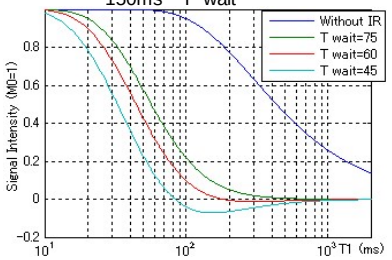


Fig. 2-1: Signal intensity simulation with/without TIS

Phantom signal intensity was compared with above 3 methods. Phantoms were as follows; Liquid oil (T1=200ms), Gd10 (Gd 10 µM/l, T1<20ms), Gd1 (Gd 1 µM/l, T1=220), NiCl2 (5.2mM/l, T1=260), Sugar44 (44%weight sugar water, T1=390), Sugar29 (29%weight sugar water, T1=940), Water (T1>2000).

A volunteer was scanned with above 3 methods. Aorta, fat, intestinal contents, kidney cortex and liver signal intensity were measured. Protocol was as follows; respiratory gate, ECG gate, 3D FIESTA, TR/TE 3.5/1.8ms, Flip angle 90, centric view ordering, scanning time 2m37s. Velocity encoding of the Flow-Prep was 96cm/s, which was measured with 2D Phase Contrast prior to the study.

Results

The result of the simulation is shown in Fig.2-1. In the case of T_wait=60ms (red line), signal intensity was flattened to zero for T1>200ms. In phantom and volunteer studies, this T_wait value was used. The results of the phantom and volunteer studies are shown in Fig.2-2. In the phantom study, signal intensity with TIS was flattened to zero except for Gd10 (red). On the other hand, signal intensity with original method increased more in shorter T1 (yellow). In the volunteer study, signal intensity of intestinal contents with TIS was 54% of the original method (blue circle). Fat, kidney and liver signals were suppressed well with TIS. The aorta signal with TIS was 83% of the original method. Volunteer images were depicted in Fig. 2-3. The TIS method suppressed intestinal contents signal more than the original method (red circle).

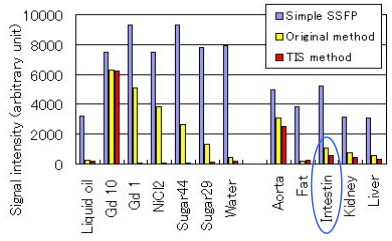


Fig. 2-2: Signal intensity measurement

Discussion and Conclusion

High background signals often overlap the aorta and arterial signals and they reduce the quality of maximum intensity projection image. Background suppression with TIS is homogeneous and insensitive to T1 in the case with T1>200ms. Because the number of RF pulses with TIS is less than original T2-Prep and SPIR method, SAR becomes lower. As a result, TIS improves vessel/background contrast and the image quality of aorta and renal artery in Non-Contrast-Agent MRA.

Reference[1]Korosec F.R.et al.,MRM 30:704-714(1993). [2]Miyoshi M.et al.,ISMRM 2006,1932. [3]Miyoshi M.et al.,ISMRM 2007,2495. [4]Dixon W.T.et al.,MRM 18:257-268(1991).

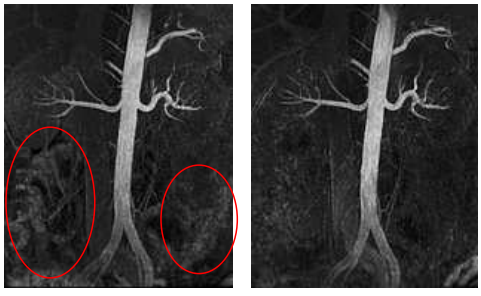


Fig. 2-3: Volunteer exam. Left: Original, Right: TIS