Non-Contrast MR Angiography with Multiple Inversion Pulses: Separation of Arteries from Veins with Flexible Inversion Time

N. Takei[1], M. Miyoshi[1], and T. Tsukamoto[1]

[1]MR Applied Science Laboratory Japan, GE Yokogawa Medical Systems.Ltd, Hino, Tokyo, Japan

Introduction

Slice selective inversion recovery (IR) is a flexible angiographic method that has been demonstrated potential application to a variety of vascular regions such as renal arteries, carotid arteries and other regions [1]. In the method to separate arteries from veins, the pulse is employed to suppress background materials like veins and static tissues in the imaged region. During inversion time (TI), blood in the arteries enters the region of interest and the Mz of the background materials is recovered because of T1 relaxation. The data is typically acquired at null point of the veins, and the contrast between the arteries and the veins is maximized. To visualize the in flowing blood as long as possible, long TI is required. However when the TI is much longer than the null point of the veins, the veins would be superimposed on the arteries. As a result, the visualization of the arteries is reduced. The purpose of the present study is to enhance depiction of arteries with longer TI, which exceeds the limitation of T1 of the veins. Multiple IR pulses of selective inversion pulse and non-selective inversion pulse are used for longer transit time of arteries.

Methods

The pulse sequence is shown in Fig.1. SIR is slice selective inversion pulse. NSIR is non-selective inversion pulse. TI1, TI2 and TI3 are inversion time from SIR, NSIR and STIR to data acquisition each. The Mz of artery, fat, vein and muscle are simulated. At the beginning of the sequence, slice selective IR was applied to tag specific arteries. After waiting time, non-slice selective IR was employed to invert all magnetizations. The inverted arteries continue T1 recovery while flowing into the imaging volume. The background signals like fat, vein and muscle started T1 recovery from –M0 at NSIR. To reduce the background signals, short Tau inversion recovery (STIR) was used before data acquisition. TI2 and TI3 were fixed to 1300ms and 1650ms, respectively. Data were acquired at null point of vein and fat. The combination of NSIR and STIR suppress the fat and the vein. It is independent to TI1 of the selective IR between 1300 and 2000 ms.

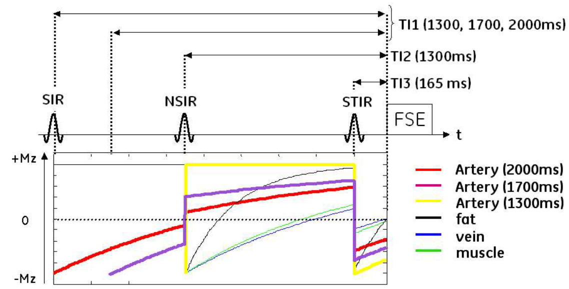

Fig.1. The schematic illustration of pulse sequence and the simulation of artery, fat, vein and muscle are shown. SIR is selective inversion pulse. NSIR is non-selective inversion pulse. The Mz of Fat, vein and muscle is nulled at the data acquisition independent on the TI1 value.

Volunteer study was performed on 1.5T EXCITE system (GE Healthcare, Milwaukee, WI) with 8-element phased array coil. Data acquisition sequence was 3D Fast Spin echo (3D FSE) (TR = 4200-4700 ms, TE = 127 ms, NEX = 0.5, flow compensation in S-I direction, ASSET factor = 2, Spatial resolution was 1.8*1.8 *2 mm). Peripheral gating was used. To acquire data in diastolic phase, IR pulses were prospectively applied. Imaging plane was coronal, which includes carotid artery from ascending aorta. Slice selective IR pulse was placed on cardiac region with thickness 140mm. Scanning times were between 4min-6min depending on TI1 and heart rates. Signal intensity and images were compared between the cases with TI1 = 1300 ms, 1700 ms and 2000 ms. The images were displayed with maximum intensity projection (MIP) and after signals from cerebral fluid and parenchyma in brain were manually removed.

Results and discussions

In the simulation, NSIR and STIR suppressed background signals of vein, fat and muscle. In the case with shorter TI1, the signal intensity of the artery is higher but in-flow time was shorter. The result of signal intensity measurement in the volunteer study is in Fig.2. The signal intensity of the artery increased with shorter TI1 as expected in the simulation. Fig.3 shows MIP carotid artery images of a volunteer. The arteries were depicted longer with longer TI1. Artifacts such as flow void and ghosting were not depicted in carotid arteries. The bilateral carotid bifurcation was clearly depicted with TI1=1700ms and TI1=2000ms. The maximum coverage from aortic arch origins to proximal cerebral arteries was achieved at TI1=2000ms (Fig. 3c). On the other hand, the subclavian artery was not depicted clearly. It is demonstrated that the multiple IR pulses method provides the longer in-flow time of arteries than T1 value of the vein and improved depiction of arteries and further TI independent background suppression.

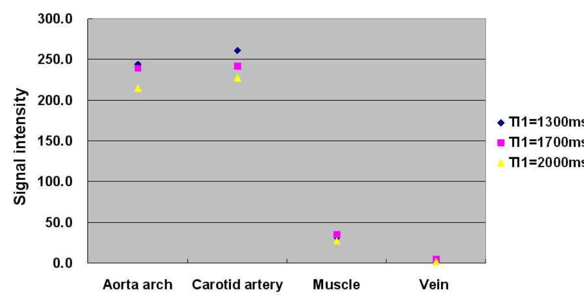

Fig.2. The volunteer result of quantitative ROI measurement. The signal intensity of the artery increased with shorter TI1 as expected in the simulation. Fig.3 shows MIP images for a volunteer. The arteries were depicted longer with longer TI1.

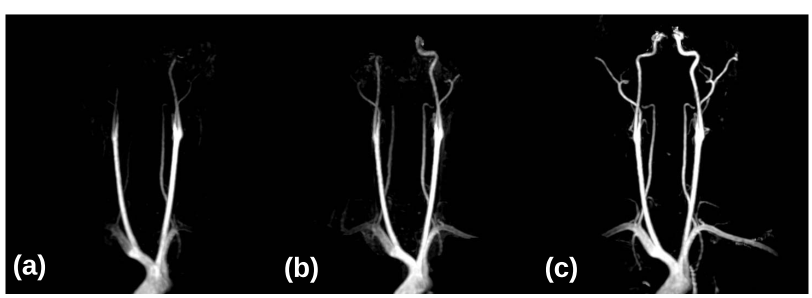

Fig.3. MIP images for a volunteer. (a) TI1=1300ms. (b) TI1=1500ms. (c) TI1=2000ms. The separation of arteries from vein with all TI1 was successfully performed. The blood depiction was improved with longer blood transit time that is identical with TI1.

References: [1] D.G. Nishimura et al, MRM, 7, 485, 1988. [2] Dixon et al. MRM, 18, 257, 1991.