

Non-contrast enhanced MRA using Inhance Inflow IR with 3D FRFSE for carotid artery imaging

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Introduction:

Non-contrast-enhanced magnetic resonance angiography (MRA) carotid imaging with time-of-flight (TOF) technique has been clinically used so far. The two main disadvantages of the method are that one is progressive saturation of inflowing spins along the slab direction. Inflow effect is reduced when slab thickness is large. Another is long scan time required 5-10 minutes to scan with a wide coverage of whole carotid artery imaging. To address these problems, we presented a new MRA technique [1], which utilizes In-Flow effect with Inversion Recovery. We call it Inhance Inflow IR. Increased inflow effect with long inversion time (TI) enables scan plane parallel to vessel direction. It provides wider coverage of scan and less scan time than conventional TOF-MRA. However cerebral spinal fluid (CSF) has longer T1 and T2 value than arterial blood and thus produced bright signal that obscures depiction of carotid arteries. The purpose of this study is to suppress CSF using fast-recovery FSE (FRFSE) with inversion pulse and to demonstrate the presented technique feasible comparing with conventional 3D TOF-MRA.

Theory:

Figure.1 shows scheme of pulse sequence. This sequence consists of three parts to suppress background tissues. First is slab selective inversion pulse with Inhance Inflow IR technique to suppress venous blood on imaging volume and to move unsaturated flowing spins into the volume during TI. Second is to employ short tau inversion pulse (STIR) to saturate fat. The combination of these inversion pulses saturates several kinds of tissue magnetizations such as fat, venous and muscle towards zero using multiple inversion technique [2]. The choice of TI is not only for venous blood suppression but also for arterial blood inflow into imaging volume. Third is to perform non-selective inversion recovery pulse placed just after FRFSE to invert CSF magnetization. The inversion pulse allows CSF magnetization to recovery slowly to around null point and allows arterial blood magnetization in cardiac region to recover fast towards the equilibrium value. Data acquisition of FSE establishes T2 weighted contrast. It gives high contrast between arterial blood and background tissues because T2 value of blood is longer than veins, muscle and fat.

Materials and Methods:

Four healthy volunteer studies were executed on 1.5T EXCITE system (GE Healthcare, Milwaukee, WI) with 8-element neurovascular phased array coil. An investigational version of the Inherent Enhancement (Inhance) Inflow IR – FRFSE was used. The slab selective inversion pulse was cardiac triggered and the trigger delay was adjusted to acquire data in diastolic phase. The inversion pulse was applied to cover the region extending from carotid bifurcation to whole brain. TI = 1500ms was selected. Imaging region covered the entire carotid arteries. Data acquisition was 3D FRFSE (Coronal scan, TR/TE = 2600-3600 / 127 ms, Refocusing flip angle = 180°, FOV = 28 cm x 28 cm, slice thickness = 2mm, #location = 46, matrix = 256x256, NEX = 0.5, ASSET reduction factor = 2, flow compensation of head to feet direction). For 3D multi-slab TOF with the same coverage of imaging and similar spatial resolution to Inhance Inflow IR, five slab multiple overlapping thin slab acquisition was performed with the following parameters:(Axial scan, TR/TE = 30/6.9ms, flip angle = 20°, FOV = 22cm x22cm, slice thickness = 2mm, #location = 10, matrix = 256 x 160, NEX=1.0, ASSET reduction factor = 2, #overlapping=6).

Results:

Figure.2 shows images of Inhance Inflow IR and 3D TOF-MRA. Carotid artery visualization was comparable. Inhance Inflow IR images displayed high contrast between blood and background. CSF was suppressed well in a region applied by slab selective inversion pulse. Averaged scan time was 3min44sec(± 9sec) and 6min18sec respectively. Slab connectivity was smooth in Inhance InflowIR because of single slab acquisition. But the depiction of intracranial arteries was better in TOF.

Discussions:

Total imaging time for scanning entire carotid arteries is shorter in Inhance Inflow IR. There is inherently high blood signal where the spins are mostly unsaturated. Slab boundary artifact is eliminated, but 3D multi-slab TOF happens inevitably. The length of carotid vessel visualization may be determined predominantly by averaged blood flow velocity and heart rate during TI. Carotid arteries have relatively rapid flow. The limitation of this approach may be the use of FSE sequence that is sensitive to recalculating or turbulent blood flow in vascular segments. Clinical evaluation with patient is needed for further validation and optimization to this approach.

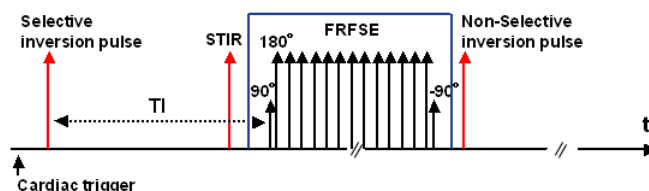


Figure.1. Scheme of pulse sequence. First spatial selective inversion pulse is cardiac-triggered and enhances blood flow with Inhance Inflow IR technique. Data acquisition is in diastolic phase. FR pulse and the adjacent selective inversion pulse suppress CSF.

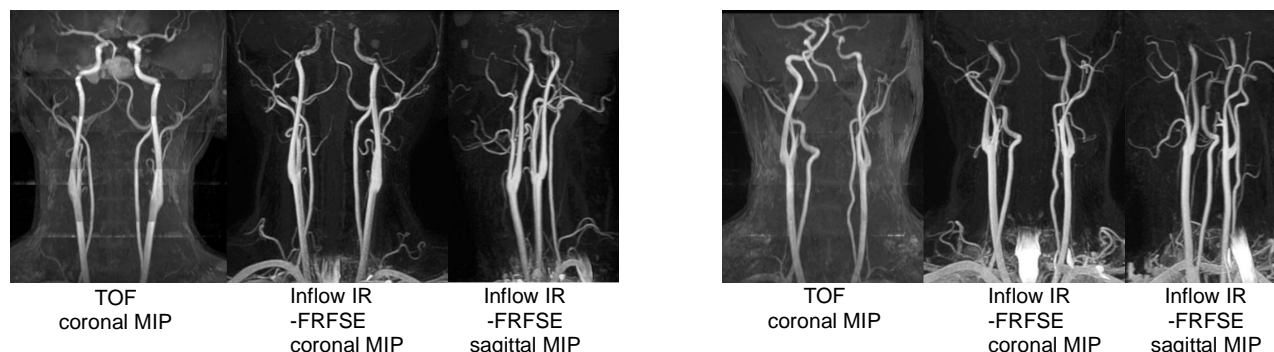


Figure.2. Comparison results between TOF and Inhance Inflow IR in two volunteers. Slab selective inversion pulse is applied to cover expanding from bifurcation below to whole brain in axial plane. Comparable vessel depiction of carotid arteries was obtained with TOF and Inhance Inflow IR. Inhance InflowIR provides excellent contrast between arterial blood and background tissues.

References: [1] Takei, N, et al., ISMRM2008 (#1988). [2] Dixon, et al., MRM, 18, 257, 1991.