A REAL-IR 3D T1-WEIGHTED BLACK-BLOOD IMAGING TECHNIQUE COMBINING WITH WHITE-BLOOD

Tokunori Kimura[1] and Kazuhiro Sueoka[2]

[1]*MRI Systems Development Department, Toshiba Medical Systems corp., Otawara, Tochigi, Japan,* [2]*Software engineering department, Toshiba Medical Systems Engineering corp., Otawara, Tochigi, Japan*

Target Audience: Researchers and clinicians who are interested in methodology for vessel wall imaging

Purpose:

Several MRI techniques for black-blood (BB) imaging were proposed and used to detect atherosclerotic plaque in carotid arteries for prevention of brain stroke. In those, 3D-T1W sequence is regarded as especially useful for detecting high-risk intraplaque hemorrhage (IPH). Recently, motion-sensitized-driven-equilibrium (MSDE) prepared 3D sequence was proposed [1]. However, motion artifacts or spatial inhomogeneity induced by eddy-current are problematic. More recently, a phase-sensitive method combining with slab-selective inversion-prepared sequence (Real-IR) was proposed [2], where IPH-to-vessel contrast was enhanced by making inflowing blood signals negative. However Wang's method has limitations for selecting the thickness of inversion slab or TI because the phase correction data is acquired after the main read-out, just for the purpose of phase correction. In contrast, homodyne filter method [3] of using self data is not required extra data for phase correction but has a risk for incorrect phase estimation on GRE sequence. The purpose of this study was to propose and assess a new 3D-T1W technique allowing to provide Real-IR black-blood (BB) images with a higher degree-of-freedom for IR-slab thickness and without extra-data acquisition only for the phase correction.

Methods:

Theory: Basic idea is that 3D-time of flight (TOF) data is employed for the background phase correction of BB data; since TOF image is acquired in addition to BB images in routine clinical diagnosis and the vessel phase becomes always the same as for the static background. Each read-out sequence was 3D-GRE (FFE) and the same TE was used to obtain the same background phase. BB is acquired with wide slab thickness of IR to invert inflow blood Mz then read-out after TI (**Fig. 1**). When TI is shorter than the TI of nulling blood Mz and without background phase error, real-part of blood signal becomes negative. In contrast, inflow blood signal in TOF data becomes positive phase. Here, S_{WB}, S_{BB} and I_{BB} are defined respectively as complex image data of WB (TOF), BB, and real BB image. Phase correction using TOF data for BB is followed by taking real part as:

$$S_{BB.cor}=S_{bb}*Conj[\ S_{WB}]\ /|S_{WB}|; \quad I_{BB}=Real[S_{BB.cor}],$$

where *Conj*[ ] and *Real*[ ]are respectively operators for taking complex conjugation and real part.

MR Experiments: Experiments were performed on Toshiba Vantage Titan^{TM} 3T (Otawara, Japan) for normal volunteer after obtaining written informed consent. For IR-BB, FFE3D, IR-slab thickness=100cm, TR/TE/FA=7.2ms/3.4ms/15deg, FOV=21cm, acquisition matrix=256x256x32, display matrix=512x512x64 after sinc interpolation, slice thickness=2mm, # of segments=2, centric-interleave (phase-slice) encode order, recovery time after read-out ($T_{recovery}$)=400ms, parallel imaging of reduction-factor=2, and TI =200~900ms was used, where acquisition time was 1:12~2:00. Fat-suppression was not added to measure T1-contrast because T1 of IPH (500ms [2]) is close to fat. For TOF, the same parameters as IR-BB were used except for missing IR pulse, TI=0 and $T_{recovery}$=0, and the acquisition time was 32s. The TOF data was used for phase correction of the IR-BB data. CNRs for tissues between sternocleidomastoid vs. TI were assessed for the Real-IR BB images.

Results and Discussion:

TOF images allowed to correct background phase on IR BB images, and thus Real-IR BB images could visualize blood vessels negatively at shorter TI (**Fig. 2, Fig. 3**), resulting in enhancing vessel-to-background tissues. The longer TI (>600ms) increased vessel signals and reduced the vessel size due to the blood T1 recovery. An optimal TI for carotid arteries (CA) on the Real-IR BB images were regarded as 400~500ms in this conditions, considering T1 contrasts among different tissues and vessel-to-background contrast (**Fig. 3**). The IR slab thickness of 30cm [2] was not enough to keep CA signal negative for longer TI due to non-inverted inflow signal. Our proposed Real-IR BB method could provide both images of TOF and high contrast BB, and then becoming available to use complementary (**Fig. 4**); and also expecting to be applied to vessel wall imaging for intracranial arteries because they were also kept negative with sufficient GM-to-WM T1 contrast (**Fig. 5**). There are several alternatives for selecting phase correction data instead of TOF. For example, like arterial spin labeling (ASL) technique [3], control images obtained with or without inversion at the same TI as tagged images, are also available, resulting in Real-IR BB and the WB-MRA images can be simultaneously obtained.

Conclusion:

Our proposed Real-IR T1W-BB is a practical method for vessel wall imaging from the views of time-efficiency for acquiring phase correction data and higher degree-of-freedom for setting IR slab thickness, though further parametric study and clinical evaluation are necessary.

References:

[1]Wang et al. MRM58:973-981(2007); [2] Wang et al. MRM69:337-345 (2013); [3] Kimura et al. MRM,62:450-458(2009); [4] Kim et al. MRM34:293-301(1995)

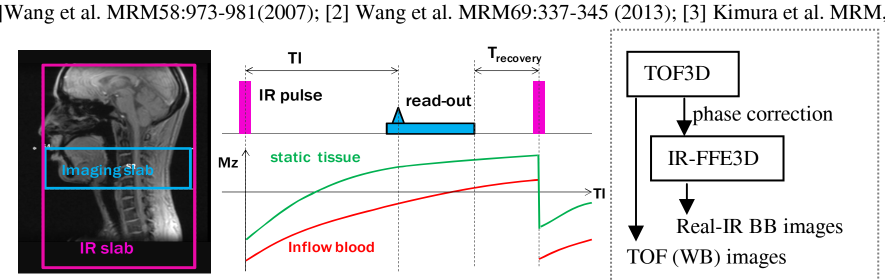

Fig. 1 Schematic for Real-IR BB technique combined with TOF

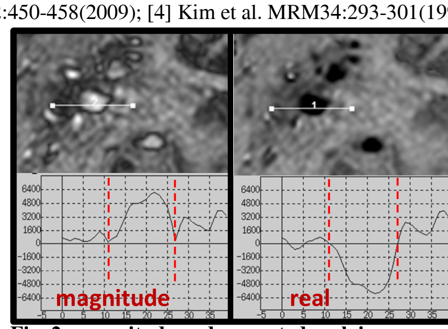

Fig. 2 magnitude and corrected real images and vessel profiles for IR-GRE at TI=500ms

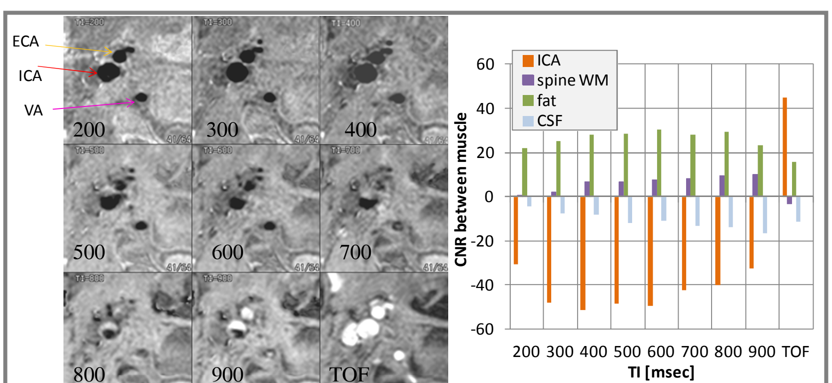

Fig. 3 Real-IR BB neck axial images with TI of every 100ms and TOF image (a), and corresponding CNR between sternocleidomastoid (b). TI of 400~500 ms is regarded as optimal from the view of CNR and blood signal suppression.

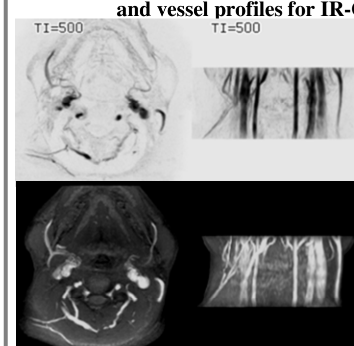

Fig. 4 min-IP'ed real-IR BB image of TI=500ms (top), and MIP'ed magnitude TOF (bottom) images.

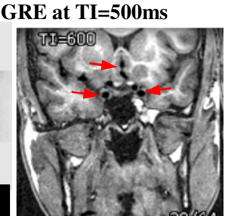

Fig. 5 Coronal brain Real-IR T1W BB image of TI=600ms. Intracranial arterial vessels became negative (arrows) with sufficient GM-to-WM T1 contrast.