NON-CONTRAST TIME-RESOLVED MR ANGIOGRAPHY COMBINING MULTIPLE IR AND N-1 SUBTRACTION ARTERIAL SPIN LABELING TECHNIQUE

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Introduction: Paired subtraction between tag and control of the same TI is indispensable for the standard ASL techniques for perfusion [1,2], because the background tissue signals are varied depending on the time after labeling (TI); it is also difficult even when inversion or pre-saturation (SAT) is not applied to imaging slab at TI=0, because the initial Mz is dependent on TI, the limited recovery time and MTC effects. A non-subtraction time-resolved MRA technique employing multiple-inversion (mIR) pulse background suppression (mIR-ASL) was proposed [3,4]. It was, however, difficult for mIR pulses less than 3 to suppress background tissue of wide range of T1 values, e.g., from fat to CSF. Excessive mIR pulses introduced the significant reduction of blood-to-background CNR due to imperfect inversion and, furthermore, restoration of longitudinal magnetization (Mz) during imaging is hard to be suppressed only by mIR. In this study, for the purpose of further suppressing background tissue signals while minimizing additional acquisition time, we proposed and assessed a technique of N-1 subtraction in combination with mIR.

Methods: In addition to multiple TI mIR-ASL images, a base image was acquired immediately after the saturation (SAT) pulse then the base was commonly subtracted from each mIR-ASL image. Basic sequence for mIR-ASL was almost the same as in Ref.4. First, the SAT pulse was applied in the imaging slab followed by two non-slice selective IR (nssIR) pulses and imaging acquisition with 3D balanced SSFP (bSSFP) was taken place after the TI from the first SAT pulse. The 3D bSSFP sequence was applied to maximize blood vessel signal with adequate spatial resolution. Durations of first and second nonselective IR pulses from SAT pulse were selected based on suppressing the brain tissue of T1=700ms (white matter:WM) and T1=900ms (gray matter:GM) at 1.5T. Imaging was performed on a 1.5-T whole-body imager (EXCELART Vantage^{TM}, Toshiba Medical Systems Corp.). Imaging conditions were; TR=5.0 ms, TE=2.5 ms, FA=120°, waiting time after imaging=100 ms, 2 segmentations with 10 dummy pulses before each segment, 3D k space with centric order (PE) and sequential order (SE), slice thickness=5mm, no. of slices=12, imaging slab thickness=6cm, FOV=22.5cm, acquisition matrix of 192x192 interpolated to 384x384, acquisition time of 16 s for base image, 26 s (TI=400ms) to 43 s (TI=1000ms), no fat saturation (FatSAT), no cardiac gating, and parallel imaging reduction factor of 2. TI was varied between 400 and 1000ms with a 200-ms increment. Magnitude subtractions of the base image from the different TI images were performed then followed by a maximum intensity projection (MIP). Volunteer brain study was performed after obtaining informed consent.

Results and Discussion: Volunteer MIP'ed images (**Fig. 1**) and the corresponding background SNR in **(Table 1)** were shown. Resulting background signals of orbital and scalp fat and brain parenchyma were further suppressed by the N-1 subtraction of base image, though not perfect. The SAT FA for base image was selected to 110° since FA greater than 90° introduced reduction of WM signal and close to that for mIR images. The WM signal in the original mIR-ASL images was almost the same as the base and constant independent of TI, while fat signal in the mIR-ASL was increasing with TI but lower than the base. Residual fat signals in the N-1 subtraction were thus due to misregistration by separate acquisitions, since MIP does not produce high signal of fat if that is lower than the brain parenchyma. A bSSFP sequence requires dummy pulses before acquiring k-space center data. If all background Mz just before the 1st dummy pulse even by SSFP, including different TI and base, can be nulled by tuning parameters or applying FatSAT, subtracted backgrounds will be zero signal. In conclusion, our proposed technique of combining a N-1 subtraction with mIR allowed a non-contrast time-resolved MRA to further suppress the background signals, though further optimization and clinical assessments are required.

References

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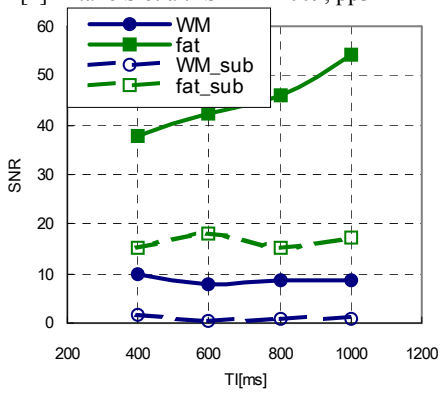

Fig.2 Background tissue SNR vs. TI for original mIR (solid) and mIR with N-1 subtraction (dashed) measured on MIPed images. Base SNR for WM and fat were respectively 10 and 63.

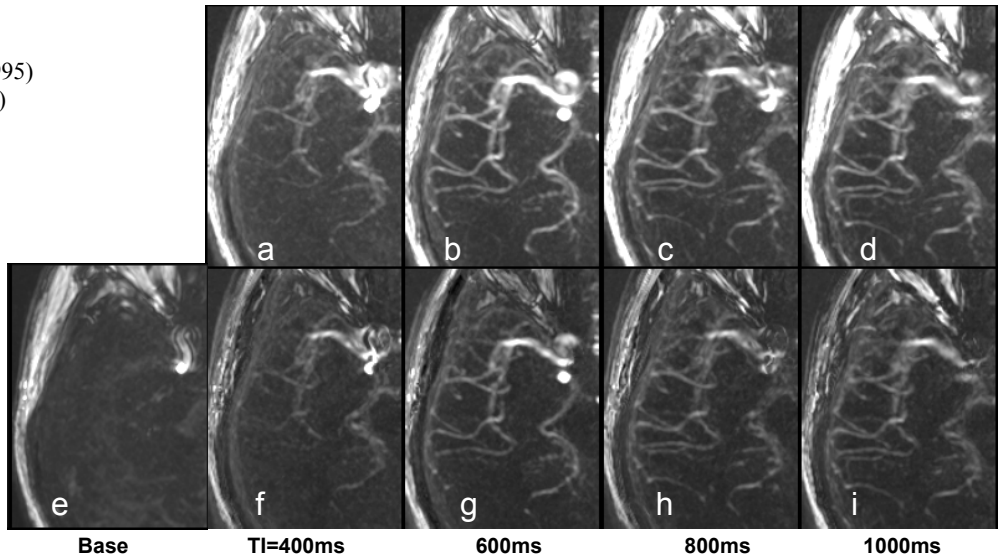

Fig.1 MIP'ed mIR-ASL MRA images at different TIs with original mIR without subtraction (**a-d**) and with N-1 subtraction (**f-i**) and the base image for subtraction (**e**). Comparing both images, the N-1 subtraction better suppressed background tissues and similarly depicted blood- vessels in this MIP direction. Note that the residual fat signals in N-1 subtraction images were due to misregistration.