Optimized Fast Simultaneous Non-contrast Angiography and intraPlaque hemorrhage (fSNAP) Imaging with low-resolution reference scan for Carotid Artery

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Introduction: Simultaneous Non-contrast Angiography and intraPlaque hemorrhage (SNAP) imaging[1] was recently proposed for carotid artery. Previous study has proven its important role for carotid atherosclerotic plaque characterizatoin[2]. By using phase sensitive reconstruction, the artery lumen in SNAP presents negative signal that can be used for non-contrast MRA, while intraplaqu hemorrhage (IPH) presents strong positive signal to be easily detected. However, a full resolution reference acquisition was used in traditional SNAP to obtain background phase for phase sensitive reconstruction, which doubles the total scan time. Recently, a fast SNAP (fSNAP) sequence[3] was proposed to reduce the total scan time by acquiring a separate low-resolution reference image. However, previous proposed fSNAP sequence must be scanned in two separated scan and additional sophisticated phase correction is needed. Moreover, the acquisition efficiency of previous fSNAP still can be improved.

Purpose: In this study, we proposed a optimized fast SNAP (fSNAP) sequence with full-resolution inversion recovery (IR) acquisition and low-resolution reference acquisition acquired interleaved in one scan to further speed up the acquisition and simplify the reconstruction for carotid artery.

Methods: *Theory:* The proposed optimized fSNAP sequence is shown in Fig. 1c. Because the background phase has low frequency property. The optimized fSNAP method used interleaved full-resolution IR scan and low-resolution reference scan after an IR pulse to speed up the acquisition. Moreover, arbitrary k-space filling order was also implemented to provide flexible contrast adjustment scheme and further shortening the scan time. IRTR and TI time were made the same as original SNAP. Compared with original SNAP sequence (Fig.1a), the TI and IRTR is preserved to generate similar contrast with shorter scan time in optimized fSNAP. Compared with previous proposed fSNAP (Fig.1b), the optimized fSNAP has higher acquisition efficiency; more importantly, the phase sensitive reconstruction is much simpler without any background phase difference in reference scan by acquiring it in one sequence.

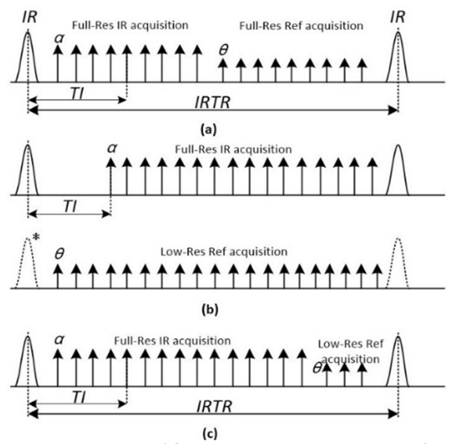

Fig.1. (a) Diagram of SNAP sequence. (b)Diagram of previous proposed fSNAP sequence with separated full resolution IR and low resolution reference acquisition. (c) Diagram of fSNAP proposed in this study, with interleaved full resolution IR and low resolution reference acquisition. Arbitrary TI time is used to further shorten the scan time and to ensure the contrast. *: No pulse.

Image Acquisition: Three healthy volunteers and one subject with carotid atherosclerotic plaque were recruited in this study. After informed consent, each subject was scanned using a 3.0T whole-body MR scanner (Achieva TX, Philips Medical System, Best, the Netherlands) with a custom-designed 36-channel head&neck coil (11 channel for carotid region). The proposed fSNAP sequence was scanned with parameters: TI 490ms, TR 10ms, IRTR 2000ms, FA11°/5°, FOV 250×160×32 mm^3, resolution 0.8×0.8×0.8mm^3, fatsat, NSA 2, turbo factor for IR scan 160, turbo factor for reference scan 40. As a comparison, the original SNAP sequence was scanned with imaging parameters: TI 490ms, linear profile order, TR 10ms, IRTR 1980ms, FA11°/5°, FOV 250×160×32 mm^3, resolution 0.8×0.8×0.8mm^3, fatsat, NSA 2, turbo factor 98. Online Reconstruction was used by zero padding the reference acquisition.

Image Analysis: The contrast to noise ratio (CNR) of SNAP and optimized fSNAP is calculated by $\frac{|mean(S_{lumen}) - mean(S_{tissue})|}{std(S_{noise})}$, where S_{lumen} is the signal of blood and S_{tissue} is the signal of muscle.

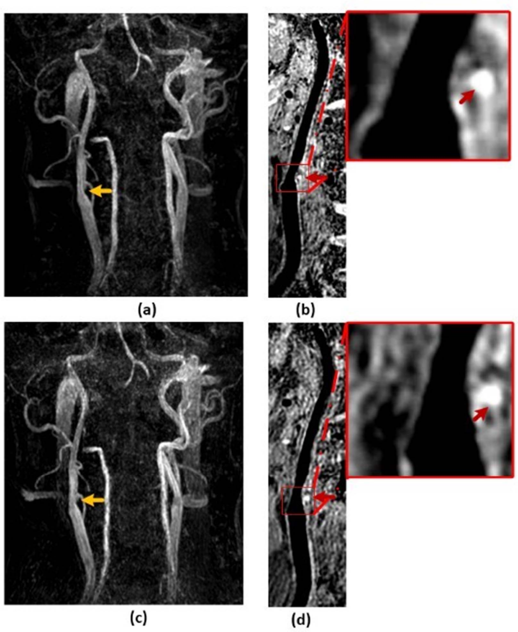

Fig.2. Comparison of the MRA and vessel wall images of SNAP (a) (b) and proposed fSNAP sequence (c) (d).

Results: The images from the patient are shown in Fig.2. The MRA of optimized fSNAP sequence (Fig.2a) is comparable with the MRA generated from SNAP sequence (Fig.2c). Stenosis (yellow arrow) can be seen in both sequences. More importantly, intraplaque hemorrhage with high signal can be detected (red arrow in Fig.2d) in optimized fSNAP, which is similar to the image of SNAP (Fig.2b). The total imaging time of optimized fSNAP was 255sec. Compared with 408sec in original SNAP, a total reduction of 153sec (37.5%) was achieved. The mean CNR of optimized fSNAP sequence is 44.35 higher than the mean CNR of SNAP which is 43.56.

Discussion and conclusion: In this study, an optimized fast Simultaneous Non-contrast Angiography and intraPlaque hemorrhage (fSNAP) sequence was proposed and validated in carotid artery. The scan time is reduced 37.5% without negatively impact the MRA quality and intraplaque hemorrhage detection. Optimized fSNAP with simple online reconstruction was found to have a similar performance compared with traditional SNAP in MRA and IPH detection, because the contrast was well preserved by using arbitrary k-space filling order. Notably, other fast imaging method could be simply added to further speed up the optimized fSNAP acquisition. Thus, optimized fSNAP is a promising tool for non-contrast MRA and intraplaque hemorrhage detection.

References: [1] Wang J., MRM. 2013; 69(2):337-45. [2] Zhao X., ISMRM 2013, p630. [3] Chen H., ISMRM 2013, p1163.