Carotid Atherosclerotic Plaque Surface Condition Evaluation Utilizing Simultaneous Non-contrast Angiography and intraPlaque hemorrhage (SNAP) Sequence

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Introduction: Carotid atherosclerotic vulnerable plaque is a major cause of cerebrovascular events, such as transient ischemic attack (TIA) and stroke[1]. Surface disruption including the present of ulceration [2] and surface calcification [3, 4], are believed to be the most important features of vulnerable plaque. Conventionally, multi-contrast sequences (T1w-TSE, T2w-TSE, 3D TOF) are used to determine the plaque components and vulnerability [5]. However, multi-contrast technique has a small coverage (32mm around carotid bifurcation) with a long scan time (>12min), limiting its translation to clinical practice. Recently, a Simultaneous Non-contrast Angiography and intraPlaque hemorrhage (SNAP) sequence [5] was proposed for carotid artery imaging. Notably, SNAP sequence contains a proton density (PD) weighted reference acquisition (Ref) without tissue suppression for phase sensitive reconstruction, which is usually discarded. This Ref image together with the MRA images generated from SNAP [5] provide an opportunity to identify the surface condition of carotid plaque with one large coverage sequence (250mm coverage in 6min42s scanning). **This study sought to evaluate the feasibility of carotid plaque surface condition evaluation using SNAP sequence alone, with the conventional multi-contrast method as a reference.**

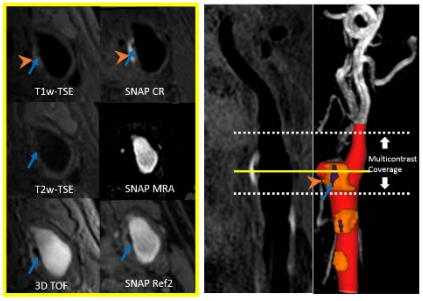

Figure 1 Example of one subject with surface calcification (blue) and IPH (orange). surface calcification (blue arrow) was identified by both conventional multi-contrast method (a. left column) and SNAP (a. right column). b.and c. shows multiple surface calcification and IPH identified on the large coverage SNAP sequence. Plaque component were perfectly registered using SNAP.

Methods: Thirty subjects (21 males, mean age 52.7 years) were selected from 328 patients with recent ischemic stroke (< 1 week) who were scanned by both SNAP and conventional multi-contrast sequences at a 3.0T whole body scanner (Achieva TX, Philips Medical System, Best, Netherlands) with a custom-designed 36-channel neurovascular coil [6]. Imaging parameters were shown at Table1. The inclusion criteria was surface disruption (Num:18) identified in multi-contrast images or subjects (Num:12) without surface disruption in the multi-contrast imaging coverage. ***Image analysis:*** Images of SNAP and 3D TOF were reformatted to transverse plane corresponding to the 2D images (16 slices× 2mm thickness). SNAP MRA images were generated using previous method [5]. A new SNAP Ref image (Ref2) was generated by weighted addition of SNAP MRA and SNAP Ref. A blinded and randomized review was performed on both SNAP images and multi-contrast images by one reviewer using Philips DICOM viewer (R3.0 SP03). For SNAP, surface disruption was identified by black signals in Ref2 near the lumen boundary (surface calcification) or as bright luminal extrusions on SNAP angiogram (ulceration) was identified by irregular plaque surface in SNAP MRA seen as crater from the lumen into the plaque. Surface disruption were also independently detected by conventional multi-contrast images. An artery based comparison was performed using Cohen's kappa tests.

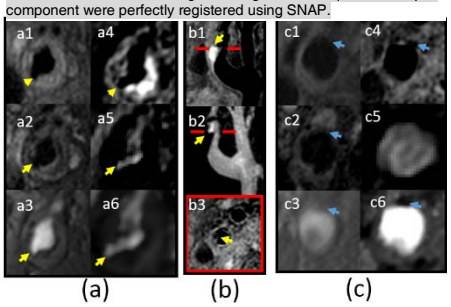

Figure 2 **a.** Ulceration in multi-contrast sequence coverage **b.** Ulceration out of multi-contrast sequence coverage **c.** surface calcification identified only by SNAP. multicontrast image: a1-a3, c1-c3; SNAP image: a4-a6, b1-b3, c4-c6;

Results: The total scan time of conventional multi-contrast sequences were 12:05 with longitudinal coverage of 32/48 mm. The total scan time of SNAP sequence was 6:45 with 250mm longitudinal coverage. A total of 60 arteries (bilateral carotid arteries for each case) were analyzed by SNAP and multi-contrast images separately. An example of identified disruption due to calcification (blue arrow) by both conventional multi-contrast method (left column) and SNAP (right column) was shown in Figure 1a. An example of ulceration identified by both method (Fig.2a) and SNAP only (Fig.2b, out of multicontrast image coverage) were shown in figure 2. And an example of luminal disruption due to calcification identified by SNAP sequence but not by the conventional multi-contrast because of motion was shown in Figure 2c. The identified surface calcification and ulceration in SNAP shows good agreement with multi-contrast method (Table 2), Kappa = 0.933, p<0.001.

Discussion and conclusion: In this study, the feasibility of plaque surface condition evaluation utilizing SNAP sequence was successfully validated. As compared to histological validated multi-contrast images, SNAP showed a good agreement in detecting surface disruption. These results, for the first time, validated that plaque surface condition evaluated by only using one 3D black-blood imaging sequence (SNAP) is feasible. Notably, SNAP sequence have a much larger coverage compared to conventional multi-contrast method with total scan time less than 7min. Furthermore, in consideration of the capability of SNAP in quantifying imaging stenosis and intraplaque hemorrhage [5, 7], SNAP sequence is potential for becoming the first-line imaging method for atherosclerotic patients.

References: [1] Golledge J. Stroke. 2000. [2] Eliasziw M. Stroke. 1994. [3] Yuan C. Circulation. 2002. [4] Saam T. Radiology. 2007. [5] Saam T. Arterioscler Thromb Vasc Biol. 2005. [5] Wang J, MRM 2013. [6] Wang X. ISMRM 2012, p2787. [7] Zhao X. ISMRM 2013, p630.

Table 1 Imaging Parameters

	Conventional Multi-contrast Method			SNAP
	T1-w TSE	T2w-TSE	3D-TOF	
FOV (RL×AP mm^2)	160×160	160×160	160×160	160×40
Longitudinal Coverage (mm)	32	32	48	250
Resolution (mm^3)	0.6×0.6×2	0.6×0.6×2	0.6×0.6×1	0.8×0.8×0.8
Scan time (min:sec)	06:11	03:50	02:04	06:45

Table 2 Comparison

		Multi-contrast	
		-	+
SNAP	-	26	0
	+	2	32
kappa		0.933	