

## Characterization of Plaque with SWI Approach: Ex vivo Study

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### Purpose

Major atherosclerotic plaque components (lipid, calcification, intraplaque hemorrhage or IH) were able to be identified with an established multi-contrast plaque imaging approach in MRI [1]. However, interscan patient motion, partial volume effect, and flow artifacts may render the accurate segmentation of plaque components difficult. Susceptibility-weighted imaging (SWI) shows capability for the differentiation of vessel wall and calcification [2]. With the availability of both magnitude and phase images in SWI, we hypothesize that the number of scans may be reduced for the purpose of identifying major plaque components. In this first initial study, the objective is to explore the role of SWI approach in the characterization of various major plaque components.

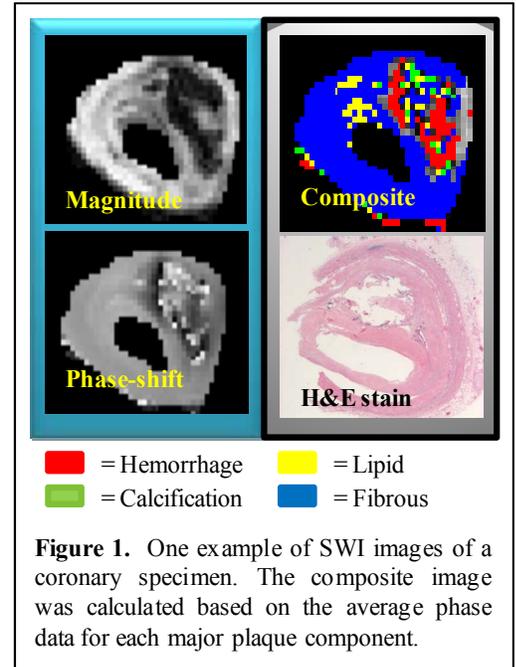
### Methods

Ex vivo MRI was performed on three phantoms that simulate hemorrhage (blood clots), lipid (intraplaque & cholesterol), and calcification (30% hydroxyapatite),

**Table** Phase data of each plaque component (IH=intraplaque Hemorrhage)

	Phantoms	Carotid Specimens	Coronary Specimens
Calcification	$1.02\pi \pm 0.87 \pi$	$1.05\pi \pm 0.46 \pi$	$0.68\pi \pm 0.08 \pi$
Hemorrhage	$-0.6\pi \pm 0.07 \pi$	$-0.65\pi \pm 0.08 \pi$	$-0.7\pi \pm 0.1 \pi$
Lipid	$0.32\pi \pm 0.08 \pi$	$-0.15\pi$ (lipid & IH)	$0.014\pi$ (lipid & IH)

respectively. Each component was immersed in agar gel. Human endarterectomy flesh carotid specimens (n = 4) and coronary artery specimens (n = 7) fixed in saline solution



**Figure 1.** One example of SWI images of a coronary specimen. The composite image was calculated based on the average phase data for each major plaque component.

were then obtained for MRI. All scans were performed in a Siemens head-only 3T Allegra system with a single-channel volumetric coil 3 cm in diameter. Multi-slice SWI imaging was first performed using a 3D FLASH sequence with flow compensation in read and slice directions (even no flow was presented). The imaging parameters included: TR/TE = 25 / 15.6 ms, flip angle = 20°, interpolated spatial resolution = 0.1 x 0.1 x 1 mm, and 24-32 slices. Multi-contrast MRI scans were then carried out in the specimen study to compare with the SWI scan. Raw data sets were reconstructed offline using home-made software to provide both magnitude and phase images after the phase unwrapping and filtering process. Pathology stains (H&E and VVG) confirmed the existence of various plaque components. ROI were drawn in the plaque components to measure the phase values. All phase data of plaque components were provided relative to the phase of adjacent agar gel (phantoms) or saline solution (specimens). In addition, the standard SWI processing, i.e., SWI (x,y, z) = magnitude (x, y, z) \* phase (x,y,z)<sup>4</sup>, was carried out to evaluate the effects of contrast enhancement on these plaque components [3].

### Results

The quantitative phase data is shown in the **Table**, with consistent results between phantoms and carotid specimens. Calcification (diamagnetic) and hemorrhage (paramagnetic) show relatively large positive and negative phases, respectively ( $P < 0.001$ ) at a TE of 15.6 ms. However, lipid has nearly zero phase change, which renders it difficult in the phase image to distinguish from other

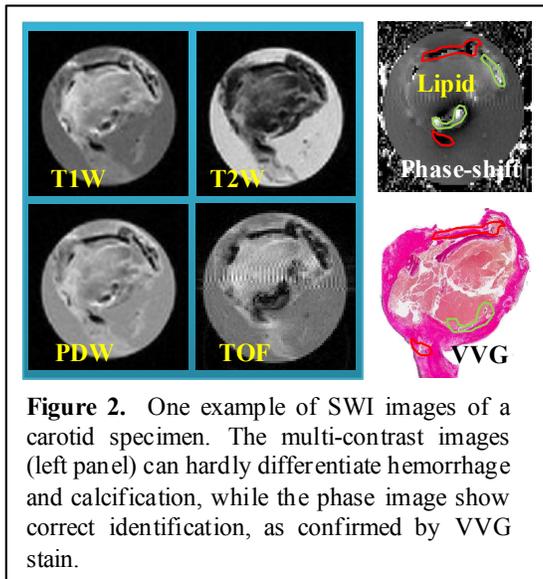
fibrotic tissue. **Figure 1** shows one example of coronary artery specimen images. The composite image based on the phase image can clearly identify the locations of calcification and hemorrhage that show hypointensity in the magnitude image. The same observation is demonstrated in the flesh carotid artery specimen (**Figure 2**). Contrast enhancement by SWI method appears minimal in our study.

### Conclusions

This ongoing study shows possibility of differentiating major plaque components using SWI approach. 3D acquisition has advantages of less flow artifacts, reduced partial volume effect, and possibly reduced scan numbers. Further effort is needed to explore quantitative methods for phase calculation such as QSM techniques [4].

### References

- [1] Hatsukami TS, et al, *Imaging Med*, 2010; 2: 63-75. [2] Yang Q, et al, *JMRI*, 2009; 30:357-365. [3] Haacke EM, et al, *MRM*. 2004; 52:612-618. [4] de Rochefort L, et al, *MRM*. 2010; 63:194-206.



**Figure 2.** One example of SWI images of a carotid specimen. The multi-contrast images (left panel) can hardly differentiate hemorrhage and calcification, while the phase image show correct identification, as confirmed by VVG stain.