COCOA and its Combination with Prospective Motion Compensation for Robust Carotid MRI

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Target audience Researchers and clinicians on Carotid imaging, as well as researchers on motion compensation techniques.

Purpose Magnetic Resonance Imaging (MRI) is currently an established tool for characterizing vessel walls in large vessels such as carotid arteries. However, the exam needs long acquisition time. For example, the scan time of a typical T1w carotid multi-slice 2D image set is over 6 minutes. Due to the long acquisition time, the image quality is vulnerable to involuntary motions, such as swallowing, blood flow and head motion. COCOA[1] is a partially parallel imaging (PPI) based method to reduce motion artifacts. It can efficiently suppress the random motion artifacts, such as swallowing. However, because it is a retrospective method, it cannot totally remove strong motion artifacts, such as serious head motion. Prospective motion detection and data re-acquisition method[2] is efficient for strong random motion artifacts, but could have residual motion artifacts because it is difficult to choose the optimal threshold to balance acquisition efficiency and motion correction. The objective of this work is to provide a motion compensation solution with improved balance of acquisition efficiency and image quality. The combination of retrospective and prospective motion compensation method is proposed. Preliminary results demonstrate that the combination of COCOA and the prospective method can consistently and dramatically reduce motion artifacts with moderately prolonged acquisition time.

Methods *Experimental setup*: Axial T1 weighted images were acquired using the black-blood Quadruple Inversion Recovery (QIR) sequence (FOV160 mm2, acquisition matrix size 260×268, TR 800ms, TE 10 ms, flip angle 90°) with a homemade 11-channel Neurovascular coil on a Philips 3T system (Philips Healthcare, Best, the Netherlands). The phase encoding direction was left-right. For preliminary clinical evaluation, two volunteers and two patients were scanned using the same protocol. The volunteers were instructed to keep still, randomly swallow, and randomly move their head in three sequential scans to produce different motion artifacts. Two sets of patient data with motion artifacts were chosen from routine clinical scans. Informed consent was obtained from the volunteers and patients in accordance with the institutional review board policy. Image quality and vessel delineation were graded on a 4-point scale (1, low SNR limits use, arterial wall and vessel margins are unidentifiable; 4, high SNR with minimal artifacts, vessel wall, lumen and adventitial margins are well defined) by 2 licensed radiologists.

Combination of Prospective and Retrospective Motion Compensation: Obital Navigator (ONAV) [3,4] was used in this work for prospective motion compensation. ONAV was repeatedly acquired during each TR, and the cross-correlation with the reference profile was calculated. If the correlation is less than a pre-defined fixed threshold, apparent motion is detected and the data will be discarded and reacquired. A low threshold (only data corrupted by strong motion will be reacquired) was used in the experiments to avoid long acquisition time. After the prospective motion compensation, COCOA was applied to the acquired data retrospectively to further reduce the residual motion artifacts.

Results In all scans, the acquisition time with ONAV was prolonged less than 10% than without ONAV. Figs 1 and 2 show the results of COCOA only, ONAV only and their combination for images with motion artifacts due to swallowing and strong head motion. Table 1 shows the image quality evaluation before and after COCOA only. From the Table, it can be seen that COCOA has the ability to suppress motion artifacts in Carotid MRI. However, residual motion artifacts can be observed (Fig 1b in the lumen and Fig 2b) if COCOA was used alone. Similarly, using only ONAV, residual motion artifacts can also be observed, as shown by the red arrow in Fig 2c. The combination of the prospective (ONAV) and retrospective (COCOA) method resulted in the least motion artifact and the best vessel delineation.

Discussion Retrospective motion compensation alone can improve image quality (Table 1, Figs 1b and 2b), but cannot sufficiently remove strong motion artifacts. When a low threshold is used in prospective motion compensation technique to avoid long acquisition time, residual motion artifacts can be found (Figs. 2c). This work shows that the combination of retrospective and prospective motion compensation technique can mitigate the problems of each individual method. Practically, a low threshold is used in prospective motion compensation technique to remove strong motion without significantly prolong the acquisition time, and the potential remaining moderate motion artifacts can be further suppressed by the retrospective motion compensation scheme. Further image quality evalution on the combined method will be followed.
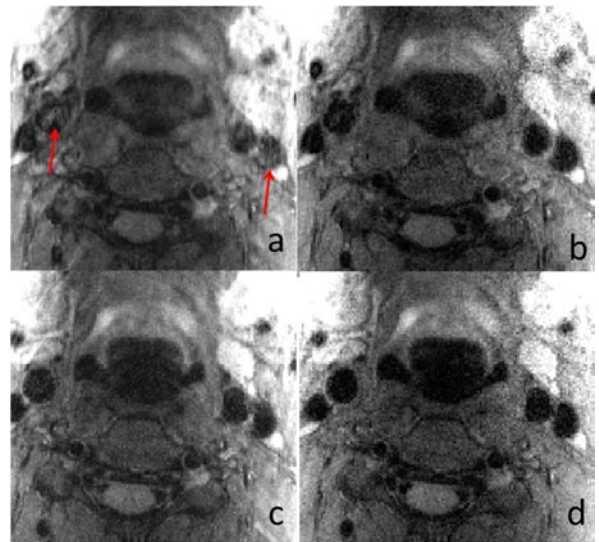

Figure 1. Results with motion artifacts due to swallowing. a) to d) are results without motion correction (a), by COCOA (b), by ONAV (c), and by the combination of ONAV and COCOA (d). The red arrows show the artifacts in the lumen.
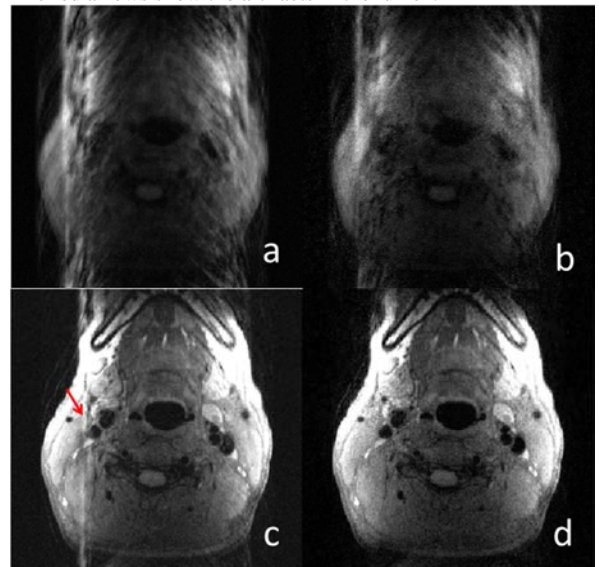

Figure 2. Results with motion artifacts due to strong head motion. a) to d) are same as these in Figure 1. The red arrow show the residual artifacts after the prospective motion correction.

	Volunteer			Patients
	Motion Free	Swallowing	Head Motion	
Original	4 ± 0	1.4 ± 0.7	1.1 ± 0.4	2.5 ± 1.0
corrected	4 ± 0	2.3 ± 0.7	1.9 ± 1	3 ± 1.0

Table 1. Preliminary evaluation with 6 sets of volunteer data and 2 sets of patient data

References : [1] Huang, F., et. al. MRM 2010;64(1):157-166   [2] Fan, Z. Y ., et. al. ISMRM 2012; 319   [3] Nielson. T ., et. al. ISMRM 2012; 2463   [4] Nielsen, T., et. al. MRM 2011;6(5):1339-1345.