Development of comprehensive 3D evaluation of atherosclerosis in multiple vascular beds

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Background: Since atherosclerosis is a systemic disease that affects all vascular beds[1], MRI can be useful in monitoring its outcomes throughout the whole body. 3D dark blood MRI is quickly becoming the preferred methodology for evaluating atherosclerotic plaque burden non-invasively [2]. It is also becoming more common to use such imaging approaches in multiple vascular beds including the aorta [3], carotids and femoral arteries [4] in an attempt to evaluate systemic disease burden instead of focusing on specific lesions. Such approaches can then be used to evaluate changes in burden in response to treatment and/or be used to evaluate progression or regression of disease over time [5]. 3D approaches are often preferred to 2D approaches because of increased SNR obtained and due to the minimization of volume averaging artifacts from 3D scans. The ability to obtain isotropic voxels thereby enabling multi planar reformatting of images is yet another benefit of 3D approaches. The most promising 3D black blood approach currently being investigated is the variable flip angle TSE (SPACE) approach [6]. Before this technique can become clinically applicable, however, its robustness must be established. For this purpose, it is increasingly important to develop a patient positioning and protocol implementation workflow for optimum reproducibility of imaging results. Here we propose the use of the 3D SPACE sequence to evaluate the carotids, aorta and superficial femoral arteries in patients at risk for cardiovascular disease using a consolidated imaging approach in the same imaging session.

Methods: 15 patients at risk for cardiovascular or atherosclerotic disease were scanned using both 3D SPACE and conventional 2D multi contrast TSE imaging. All MR images were obtained on a 1.5T Siemens whole body MR imaging system. The scans were divided into 3 segments for appropriate anatomical coverage. First, the carotids were scanned extending 3 cm below and above the carotid bifurcations using a 4-channel carotid coil. Secondly, the entire length of the aorta from the aortic arch to the iliac bifurcation was scanned using the spine array and two body matrix coils. Finally, the iliacs and the bilateral superficial femoral artery were also imaged using the spine array and body matrix coil. Imaging was performed using a 3D cardiac gated scan with navigator control for respiratory gating SPACE sequence for the aortic images and using a non-cardiac and respiratory gated SPACE scan for carotids and femoral arteries. Image resolution was approximately 1.1mm isotropic voxel for the aorta and approximately 0.8mm isotropic voxel size for the carotids and approximately 1mm isotropic voxel size for femoral imaging. 12 slice 2D TSE images using multi-contrast weightings and using parallel saturations bands for flow suppression were also obtained for all three vascular beds for comparison purposes. The in -plane resolution for 2D scans was 0.7mm for aorta and 0.5mm for carotids and femorals. Images were subjectively evaluated for 4 distinct criteria (overall image clarity, vessel wall delineation, flow suppression and artifacts) using a 5 point scale ranging from 1-5 with 1 being poor and 5 being excellent [8]. A Mann-Whitney rank sum test was used to compare the scores obtained using the qualitative analysis. A p-value < 0.05 was considered significant. Total imaging time was < 45 minutes for all three vascular beds combined for the 3D scans. The 2D scans also took 45 minutes to cover the same vascular territory.

Table 1: Mean and SD of Qualitative Assessments

Vessel	Sequence	ImQ	VWD	FS	Artifacts
Carotids	2D TSE	4.0 ± 0.67	4.3 ± 0.67	4.2 ± 0.63	4.1 ± 0.73
Carotids	SPACE	3.7 ± 0.67	4.2 ± 0.78	4.5 ± 0.52	3.9 ± 0.73
Aorta	2D TSE	3.9 ± 0.73	4.0 ± 0.67	3.8 ± 0.63	3.4 ± 0.84
Aorta	SPACE	4.0 ± 0.67	4.3 ± 0.82	4.1 ± 0.56	3.6 ± 0.84
Femoral	2D TSE	3.9 ± 0.73	3.4 ± 0.84	3.5 ± 0.85	4.0 ± 0.67
Femoral	SPACE	2.8 ± 0.79*	2.3 ± 0.94*	2.4 ± 0.96*	3.1 ± 0.57*

ImQ: image quality; VWD: vessel wall delineation; FS: flow suppression; * indicates significant difference ($p < 0.05$)

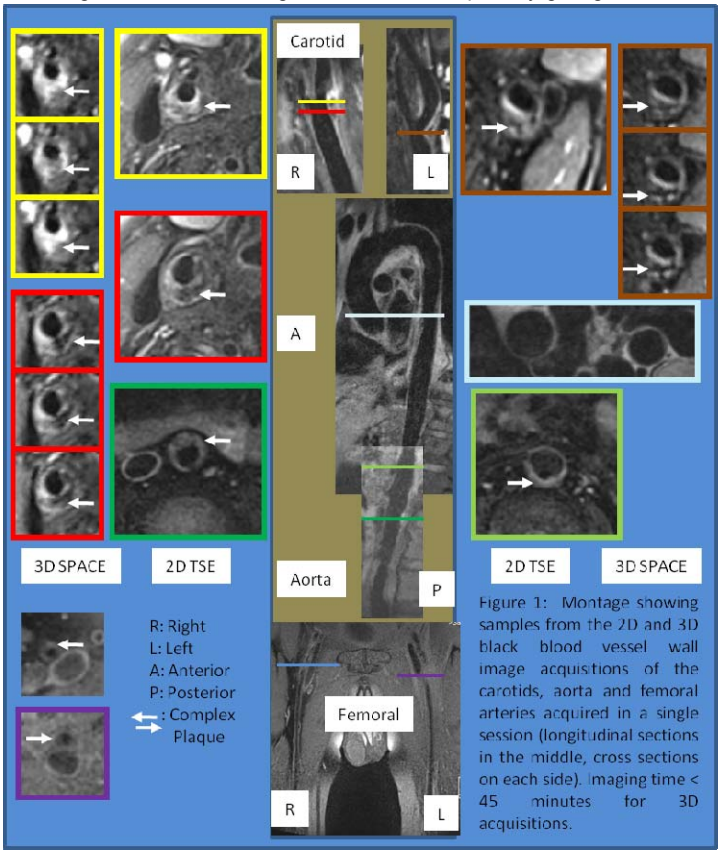

Figure 1: Montage showing samples from the 2D and 3D black blood vessel wall image acquisitions of the carotids, aorta and femoral arteries acquired in a single session (longitudinal sections in the middle, cross sections on each side). Imaging time < 45 minutes for 3D acquisitions.

Results: Images using 2D TSE and 3D SPACE were successfully acquired from all15 subjects for all three vascular beds. Sample images obtained are shown in Figure 1.The qualitative analysis results are presented in Table 1. Results indicated that for carotids and aorta, there was no significant difference between the 2D TSE and SPACE approaches qualitatively. For femoral imaging however, the SPACE sequence fared more poorly in all criteria indicating that the current protocols for femoral imaging needs improvement to be compared to traditional 2D imaging. This might have to do with the smaller size of the femoral arteries and poorer resolution in plane of the SPACE sequence or lack of specialized coils for femoral imaging. Partial voluming effects were however higher in the 2D images and therefore plaque burden estimation using 3D SPACE is expected to be more robust.

Conclusions: 3D SPACE appears to be an excellent imaging approach to determine overall plaque burden in multiple vascular beds in the same imaging session. Subjective image quality is comparable to 2D TSE approached while providing advantages of more accurate burden measurements and improved vessel wall coverage with same scan time.

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