Creating a one-stop shop? 3D black blood vessel wall imaging would combine information of luminal severity and plaque composition

L. Dong[1], H. Shen[2], X. Zhang[1], W. Yu[1], Z. Zhang[1], H. Guo[3], R. Wang[1], D. Lu[1], and C. Yuan[3,4]
[1]Capital Medical University, Beijing Anzhen Hospital, Beijing, Beijing, China, People's Republic of, [2]GE Healthcare, [3]School of Medicine, Tsinghua University, [4]University of Washington

Background: Current clinical standard for diagnosing carotid atherosclerosis is angiography, which determines the location and severity of luminal stenosis. Whereas vessel wall magnetic resonance imaging (MRI) depicts atherosclerotic plaque composition, which has been correlated with increased risk of cerebrovascular events [1, 2]. As such, the ideal is to assess both luminal stenosis and plaque vulnerability comprehensively during a signal session. Previous studies found that a 3D based black blood sequence is feasible for assessing carotid artery [3, 4]. However, whether its capability for identification carotid stenosis and plaque characteristics remains unknown.

Purpose: We hypothesized that the 3D black blood, a single sequence, can quantify carotid stenosis and plaque composition simultaneously. To test this hypothesis, we sought to (1) compare images from the 3D black blood with contrast-enhanced MR angiography (MRA) in measuring the carotid stenosis; (2) compare the 3D black blood with corresponding histology in identifying major plaque components: lipid core (LC), intraplaque hemorrhage (IPH), and calcification (CA).

Methods: Nine subjects with known or suspected carotid atherosclerosis underwent carotid MRI examinations on a 3T scanner. High-resolution 3D SPGR (TR/TE = 6.9/3.2ms, FA = 8˚, FOV = 140mm x 112mm, matrix = 256 x 205. NEX=0.75, slice thickness = 20, 20 slices) sequence was prepared with a flow suppression technique (Spatial LabEling with multiple invErsion pulses, SLEEK, TI = 500 for inflow blood suppression), and followed by a waiting period (TW = 900ms) for relaxation. The total scan time was 4min52sec. An additional 3D contrast enhanced MRA was acquired in the coronal plane with 3D FSPGR sequence (TR/TE: 2.5/ 1.2 ms; Flip angle: 40°; slice thickness: 2 mm; partitions per 3D slab: 36; matrix: 192 X 320; field of view: 320 mm; number of excitations: 1). Two experienced radiologists independently interpreted all bilateral carotid MRA images and 3D SPGR images. Luminal stenosis was quantified in both carotid arteries using the NASCET criterion: (1 - luminal diameter at the point of maximal narrowing / the diameter of the normal distal internal carotid artery) x 100% [5]. All diameter measurements were acquired using GE software (GE medical system advantage workstation 4.2.) and were oriented on MIP/MPR images. One trained reviewer, blinded to histological results, determined plaque components using criteria that have been validated with 2D multi-contrast weighted images [6]. The criteria for identifying plaque components on 3D SPGR are (1) CA is no signal; (2) IPH is hyper-intense signal; (3) LC is hypo-intense signal. Spearman's rank correlation coefficient was used to determine agreement between 3D SPGR and MRA in measuring luminal stenosis.

Results: Bilateral carotid arteries (n=16) were included in the final analysis after 2 arteries were excluded due to occlusion. There was an excellent correlation of measuring stenosis between 3D SPGR and MRA ($r = 0.95$, $p < 0.001$). For those arteries with corresponding histology (n = 5), 3D SPGR identified all CA accurately (Table 1). It was less sensitive for IPH detection (Table 1). There was good agreement between 3D SPGR and histology for LC detection (Table 1). Representative cases are shown in figures 1-2.

Table 1. Identification of plaque components on MRI and histology

		Histology					
		LC		IPH		CA	
		Yes	No	Yes	No	Yes	No
3D black blood	Yes	4	0	2	1	4	0
	No	1	0	1	1	0	1
Agreement		80%		60%		100%	

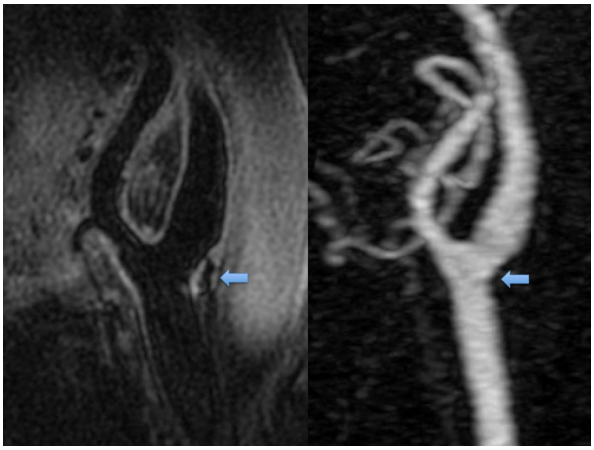

Fig 1. Mild luminal stenosis is seen on the 3D black blood image (left) at carotid bifurcation (arrow), the good corresponding on MRA (right).

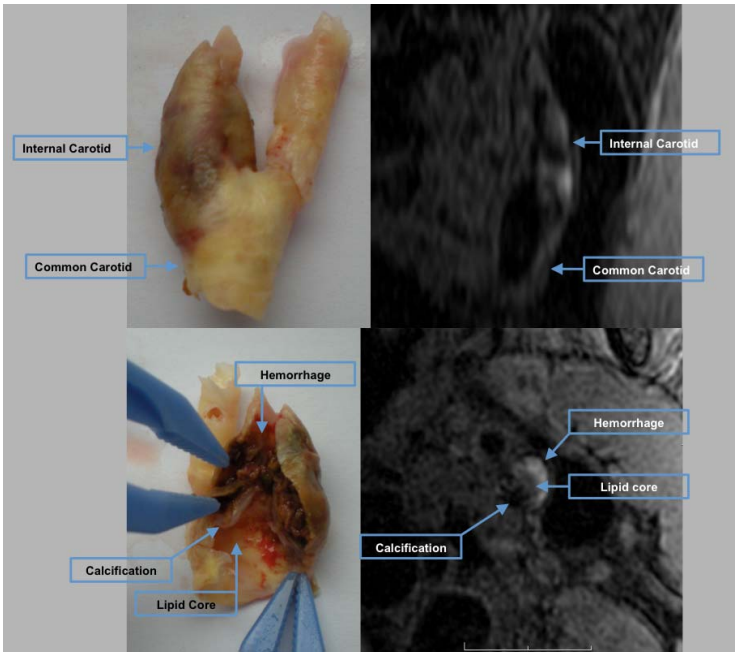

Fig 2. Corresponding to histology, calcification, lipid core, and hemorrhage are also visualized on reformatted axial and sagittal 3D black blood images.

Discussion The results demonstrate that the 3D black blood, a single sequence, can quantify carotid stenosis and plaque composition. The 3D black blood images allow interactive reconstruction in arbitrary planes providing a more thorough visualization of luminal severity and plaque components. In addition, this fast sequence may benefit patients who suffer from intolerance of long scan time.

Conclusion

The 3D black blood image is capable to measure luminal stenosis and plaque composition in carotid artery, which providing angiographic lumen information and identifying high-risk plaque features simultaneously. For future clinical trials using carotid MRI, the 3D black blood technique could be applied as a screening tool.

Reference

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