Association of Arterial Compliance between Carotid Artery and Abdominal Aorta and Its Role in Assessment of Carotid Atherosclerotic Disease: A 3.0T MR Imaging Study

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Introduction: Compliance is a biomechanical characteristic of the vessel wall that is defined as the relative change in cross-sectional area or vessel diameter against unit pressure change. Arterial compliance, as a systemic indictor for vascular degeneration with aging, may vary among different vascular beds due to local disease status [1-2]. There is a debate in the correlations between arterial compliance and cardiovascular disease risk. Previous studies have shown that vessel wall compliance is associated with atherosclerotic disease [3-6]. Other investigators demonstrated that aortic compliance does not predict the presence of coronary and extracoronary atheroma [7]. The correlations of arterial compliance among different vascular beds and its role in assessment of atherosclerotic disease risk are still unclear.

Purpose: This study sought to determine the correlation of wall compliance between carotid artery and abdominal aorta and with carotid atherosclerosis using MRI.

Methods: ***Subjects:*** Twenty subjects (10 male, mean age 71.8±6.4 years) who participated in a community study named Cardiovascular Risk of Older Population (CROP) were recruited in this study. The systolic and diastolic blood pressures were measured during each visit. ***MR imaging:*** Participants underwent MR imaging on a 3.0T whole-body MR scanner (Achieva TX, Philips Medical System, Best, The Netherlands) with a custom-designed 36-channel neurovascular coil [8]. A 2D balanced turbo field echo sequence (b-TFE) was applied for acquisition of arterial CINE images of bilateral carotid arteries and abdominal aorta with 15 cardiac phases. Three slices below the bifurcation of carotid artery and 2 slices for abdominal aorta (1cm above and below renal artery level) were acquired, respectively. The imaging parameters are as follows: TR/TE 4.19/2.10 ms, flip angle 40°, matrix 210×210, field of view 140×140 mm^2, slice thickness 3 mm, slice gap 0 mm. Images were then stored and analyzed offline for future measurements and calculations. Black-blood vessel wall imaging was performed for bilateral carotid arteries using 3D MERGE imaging sequence [9] with the following parameters: FFE, TR/TE 9.2/4.3 ms, flip angle 6°, FOV of 250 x 160 x 40 mm^3, spatial resolution 0.8 x 0.8 x 0.8 mm^3. ***Image analysis:*** The carotid 3D MERGE images were reconstructed using Philips workstation with 2mm slice thickness cross-sectionally centered to the index side (the smaller lumen size between two sides) of carotid bifurcation. All CINE and axial carotid MR images were imported into a custom-designed software (CASCADE [10], Seattle, WA, USA) for further analysis. The luminal boundaries of both carotid artery and aorta for each cardiac phase were then traced (Fig. 1) by two experienced reviewers with consensus blinded to 3D MERGE images. Blinded to CINE images, two different reviewers measured carotid plaque burden including lumen area (LA), wall area (WA), mean and maximum wall thickness (Mean WT/Max WT), and normalized wall index (NWI=WA/[LA+WA] x 100%), by outlining the lumen and wall boundaries of carotid cross-sectional images. MR measure of compliance was defined as the normalized maximal cross-sectional change in vessel area over aortic pulse pressure to minimize the variation of compliance measurement due to the size of different vascular beds. The relationship of arterial compliance between left common carotid artery (CCA), right CCA, and abdominal aorta was evaluated using the Pearson correlation coefficient. The correlation between carotid plaque burden and wall compliance of CCA and aorta was also determined.

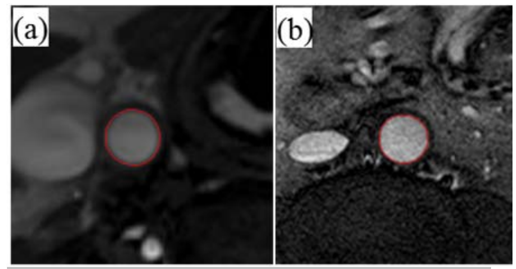

Fig.1 Example of manual delineation of lumen boundary for right CCA (a) and abdominal aorta (b).

Results: The compliance of left CCA, right CCA and abdominal aorta was 18.7±6.4 x 10^{-3}/kpa, 16.8 ± 5.7 x 10^{-3}/kpa, and 14.1 ± 6.1 x 10^{-3}/kpa, respectively. The compliance of abdominal aorta was significantly lower than that of left CCA ($P<0.001$). There was strong correlation of compliance between abdominal aorta and left CCA ($r=0.796$, $P<0.001$, Fig. 2a). No significant correlation between abdominal aorta and right CCA compliance was found ($r=0.155$, $P=0.514$). Carotid plaque burden measurements were summarized in Table 1. Wall compliance of left distal CCA was significantly correlated with carotid Mean WT ($r=0.544$, $P=0.044$), Mean NWI ($r=0.688$, $P=0.007$), and Max NWI ($r=0.685$, $P=0.007$) (Fig. 2b-d). There was no significant correlation between carotid plaque burden and abdominal aorta and right CCA compliance (all $P>0.05$).

Table 1. Summary of carotid plaque burden measurements.

Carotid plaque burden	Mean±SD		P
	Left side	Right side	
LA, mm^2	46.3±16.8	45.1±11.6	0.807
WA, mm^2	22.2±8.1	27.0±4.3	0.043
Mean WT, mm	0.8±0.2	1.0±0.1	0.009
Max WT, mm	1.5±0.9	1.8±0.7	0.244
Mean NWI, %	34.3±8.5	39.6±3.2	0.026
Max NWI, %	42.7±9.3	49.0±5.9	0.029

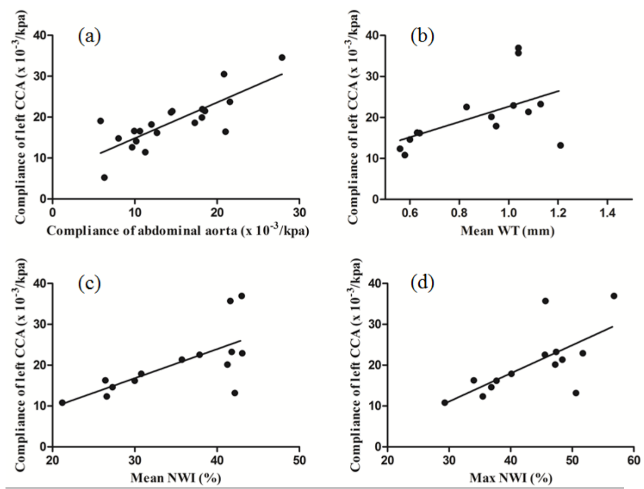

Fig. 2 Correlation of compliance between left CCA and abdominal aorta (a) and carotid plaque burden measurements including MeanWT (b), Mean NWI (c) and Max NWI (d).

Discussion and Conclusions: In this study, we investigated the correlation of wall compliance between carotid artery and abdominal aorta and with carotid atherosclerosis. We found that wall compliance of CCA was greater than that of the abdominal aorta. Our findings are in line with previous studies [1-2]. In our study, abdominal aorta compliance was strongly correlated with left CCA, indicating that wall compliance is a systemic biomechanical property which reflects the degeneration of wall structure. These findings suggest that compliance measurement in one vascular bed might be an indicator for other vascular biomechanical characteristics. In addition, we observed that the correlation of abdominal aorta compliance with that of left and right CCAs is asymmetric which may be due to the different anatomic and hemodynamic characteristics between bilateral carotid arteries. We also found that wall compliance of left CCA was related to carotid plaque burden suggesting that wall compliance might be a potential indicator for severity of atherosclerotic disease.

References: [1] Länne et al. J Vasc Surg. 1994;20:218-25. [2] Paini A, et al. Hypertension. 2006;47:371-6. [3] Lind L,et al. Clin Physiol Funct Imaging. 2009;29:321-9. [4] Lind L, et al. J Hypertens. 2006;24:1075-82. [5] Scuteri A, et al. Aging Clin Exp Res. 2006;18:452-61. [6] Lee JM, et al. Diab Vasc Dis Res 2007;4:44–48. [7] Megnien JL, et al. Am J Hypertens. 1998;11:293-301. [8] Wang X, et al. ISMRM 2012, Melbourne, Abstr. #2787. [9] Balu N, et al. MRM. 2011;65(3):627-37. [10] Kerwin W et al. Top MRI. 2007;18:371-378.