Increasing spatial resolution alters measurement variability of carotid plaques

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Introduction: Improved risk stratification of patients with atherosclerosis has the potential to improve treatment strategies and outcomes for patients at moderate and high risk for atherosclerotic events. Magnetic resonance imaging (MRI) has been shown to be capable of providing reliable measurements of vessel wall dimensions and morphological plaque constituents, such as the necrotic lipid rich core and intraplaque hemorrhage, both suggested by several histopathological studies to be the hallmark of the vulnerable plaque[1-2]. In addition, MRI has the potential beyond diagnostic and prognostic purposes to serve as a surrogate marker in clinical trials. In such studies, MRI has been shown to deliver excellent quantitative measurements of the vessel wall and has the potential to investigate the effect of interventions directed at morphological plaque characteristics. Commonly images are obtained with 0.5 mm in plane resolution. We hypothesize that increasing the spatial resolution to 0.25 mm in plane has the potential to improve image quality and thus improve morphological characterization of the atherosclerotic plaque. The purpose of this study was to compare high (HR) and low (LR) spatial resolution measurement variability of both plaque dimensions and morphological composition at 3T MRI with the use of a multicontrast protocol in a population with significant carotid atherosclerosis.

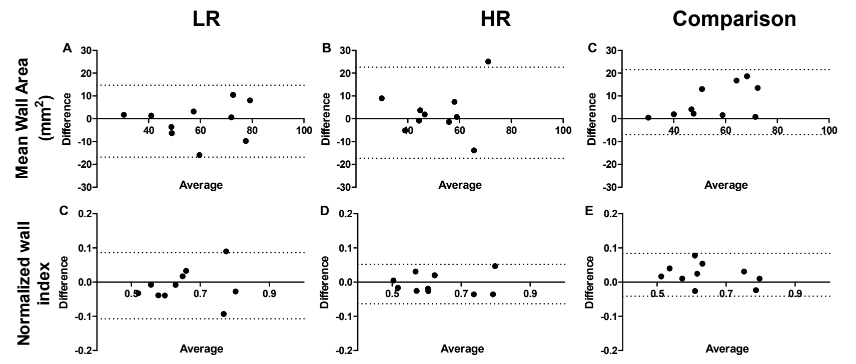

Fig 1: Bland-Altman plots for both LR (A and C), both HR (B and D) and for the average LR versus the average HR scans (C and E) of the mean wall area (MWA) and the normalized wall index (NWI). The dotted lines represent the lower and upper 95% limits of agreement.

Methods: In each of the 10 subjects of the study two 3.0 Tesla MRI carotid scans were performed on a Philips Intera scanner within one month. For imaging of plaque size and composition unilateral axial turbo spin echo T1w, T2w, PDw and Time of Flight (TOF) image stacks were acquired at late diastole (ECG gated). Sequence parameters were: FOV 60 x 60 mm, double inversion-recovery black blood prepulse, T1w: TE 8 ms and repetition time (TR) according to heart rate (around 800 ms), T2w: TE 50 ms and TR according to heart rate (around 1700 ms); PDw: TE 8 ms and TR same as T2w; TOF: TE 7 ms, TR around 35 ms and flip angle 20˚, slice thickness 2 mm, non-interpolated pixel size 0.25 x 0.25 mm (HR) or 0.5 x 0.5 mm (LR) and active fat suppression (SPAIR) for T1w, T2w and PDw. MR image analysis was performed using semi-automated measurement software (VesselMass, Leiden University Medical Center, Leiden, The Netherlands). Luminal and outer vessel wall contours were delineated and Mean wall area (MWA), Mean wall thickness (MWT), lipid and calcium area were subsequently quantified. NWI was calculated by dividing the vessel wall area by the outer contour area.

Results and Discussion: Bland-Altman plots of the MWA and the NWI suggest a systematic difference between the HR and LR imaging protocol (Figure 1, panel C and E). HR imaging improves the reproducibility for the NWI. In line with these findings are the means and SD of the paired differences of the LR, HR and the LR versus the HR protocol for the MWA and the NWI (Table 1). For the MWT, lipid and calcium area measurement variability varies among the HR and LR measurements. Figure 2 shows an example of an image (Figure 2, panel C versus panel F), where an increased spatial resolution results in a more accurately identified calcium area contour. In contrast, measurement variability of HR imaging for calcium contours is larger than LR variability, highlighting that a sharper image not always translates into an improved reproducibility.

	MWA (mm^2)	NWI	MWT (mm)	Lipid (mm^2)	Calcium (mm^2)
Mean (SD) of pd					
HR 1 vs HR 2	2.67 (10.2) n=10	0.006 (0.029) n=10	0.175 (0.536) n=10	1.43 (3.26) n=4	0.736 (2.41) n=9
LR 1 vs LR 2	1.02 (8.03) n=10	0.011 (0.049) n=10	0.067 (0.227) n=10	3.12 (4.60) n=6	0.047 (1.27) n=8
HR vs LR	7.33 (7.27) n=10	0.593 (0.090) n=10	0.285 (0.282) n=10	3.30 (3.04) n=4	1.02 (1.67) n =8

***Table 1:** Means and standard deviations (SD) of the paired differences between scans, for all subject are shown. pd= paired differences, MWA = mean wall area, NWI = normalized wall index, MWT = mean wall thickness.*

Differences of calcium contours on PD weighted images

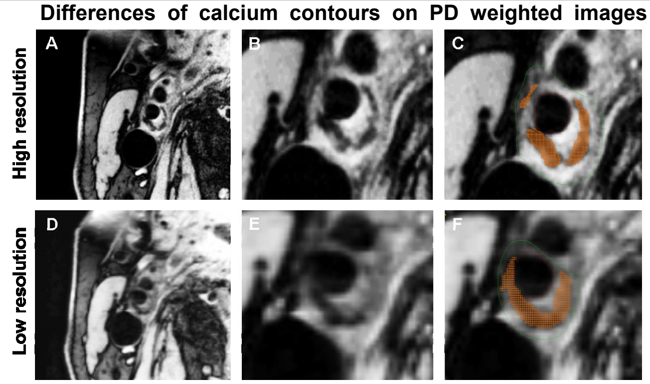

***Fig 2:** High (A and D) and low resolution (B and E) PDw images of an atherosclerotic plaque. Panel C and F show a calcium area contour on a hypodense area. The calcium contour is drawn more selective on the HR image.*

Conclusion: In this population we have shown that both LR and HR show good measurement reproducibility for MWA, NWI and MWT. In addition our data suggests that accuracy and reproducibility differ among high and low resolution scanning protocols for vessel wall dimensions and plaque morphology. Further research is necessary to determine optimal imaging resolutions tailored to the specific measurements of interest, measurement reproducibility and accuracy.

[1]Yuan et al. Circulation 2001; 104;2051. [2] Feiiyu et al. JMRI;2010; 31:168.