Comparison between carotid wall T1,T2 quantifications with and without 3D iMSDE reference scan

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INTRODUCTION:

Quantitative T1 and T2 vessel wall imaging is emerging as a novel strategy for assessing atherosclerotic plaque components in the carotid artery [1,2]. Recently, in vivo 3D carotid artery T1 and T2 mapping was demonstrated using a 3D iMSDE black-blood sequence and fitting images with variable flip angle (α) and variable TE preparation times (TEprep) [2]. Prior to T1 and T2 estimation, all acquired images need to be registered to account for possible movements between scans. Instead of relying solely on the quantitative scan, a separate high SNR 3D iMSDE reference scan (3D ref) may be acquired to guide the registration, as well as subsequent vessel wall segmentation. On the other hand, including an additional scan might also increase variability of the T1 and T2 estimates.

Aim: In this study, we therefore aim to investigate the influence of including a 3D iMSDE reference scan for carotid artery T1 and T2 mapping with variable flip angle and TEprep acquisitions. In addition, we investigate the feasibility to apply automated vessel wall segmentation in the 3D data, since manual segmentation on each slice of this large dataset can be challenging. These experiments will inform the choice of method for future development and clinical implementation.

METHODS AND MATERIALS:

T1 and T2 mapping: Four elderly volunteers were scanned on a 3.0T Philips Ingenia MR scanner. For carotid T1 and T2 mapping, a total of four (scan 1-4) 3D RF-spoiled iMSDE black-blood images were acquired with variable α and variable TEprep ,according to the proposed sequence [2] and using the following parameters: TR/TE = 10/3.65 ms; FOV = 156x156x25 mm^3 (coronal view), resolution = 0.7x0.7x0.7 mm^3, number of averages = 1.In addition, a non RF-spoiled 3D iMSDE reference scan (3D ref) with 2 signal averages was acquired with same geometry as the quantitative scans. Coronal images were reformatted to axial view with a 0.7-mm slice thickness. Image registration was performed on the axial images of scan 1-4 using custom software based on a published optimal method for carotid MR image registration [3]. Assuming the appropriate signal model, T1 and T2 maps were calculated from scans 1-4 using maximumum likelihood estimation ***Artery of interest:*** For each volunteer, two segments of left carotid were analyzed: (1) common (CCA), > 4 mm proximal to the bifurcation; (2) internal (ICA), > 0 mm distal to the bifurcation. The longitudinal coverage for analysis was 6.3 mm for both segments. ***Manual segmentation:*** one observer delineated the lumen and outer wall boundaries on 5 CCA and 5 ICA slices on the 3D ref image . ***Automated segmentation*** Automated lumen and outer wall segmentation, based on the fitting of 3D tubular model [4], was applied to the CCA and ICA segment respectively. ***Relaxometry pipeline:*** T1 and T2 quantification in the carotid wall based on the following pipelines were investigated:

1) With 3D ref: ① automated segmentation was performed on 3D ref images; ② 3D ref image was used as fix image in the process of image registration.
2) Without 3D ref: ① combined image of scan 1-4 was calculated by taking the average after registration; ② automated segmentation was performed on this image; ③ Image of scan 1 was used as fix image in the process of image registration.

Statistical analysis: Lumen area (LA), outer wall area (OA), vessel wall area (WA) and median of carotid wall T1, T2 value were calculated on each slice having manual delineation. Alignment was performed manually to make sure the comparison between datasets of two different registrations was executed at the same slice location. ① To evaluate the quality to use the combined image for vessel wall segmentation, correlation coefficient (CC) of LA, OA and WA was calculated between segmentations based on 3D ref and combined image. ② To evaluate the registration effect on the mapping, the quality of fitting was measured based on the image noise level, and the lower the noise level the less fitting error. Paired t-testing was used to compare the mapping quality based on different registrations. ③ To assess the T1,T2 quantification with and without 3D ref, CC of median wall T1,T2 was calculated.

Table 1 Comparison of morphology measurements between segmentations based on 3D ref and Scan 1-4

Measurement	Pearson correlation coefficient			
	Manual vs Auto 3D ref		Manual 3D ref vs Auto Scan 1-4	
	CCA	ICA	CCA	ICA
Lumen area	0.99	0.98	0.96	0.97
Outer wall area	0.97	0.95	0.97	0.91
Wall area	0.84	0.77	0.78	0.72

Table 2 Comparison of fitting quality based on registrations: (1) 3D ref as fix image; (2) Scan 1 as fix image

Artery segment	Image noise level within vessel wall in a slice (mean ± sd):		p-value (Paired t-test)
	3D ref	Scan1	
CCA	0.73 ± 0.12	0.76 ± 0.12	0.0042
ICA	0.77 ± 0.13	0.82 ± 0.14	< 0.0001

Table 3 Comparison of T1,T2 quantification with and without 3D ref

artery segment	Measurement in vessel wall	Pearson correlation coefficient	
		3D ref	3D ref vs Scan 1
		Manual vs Auto 3D ref	Manual 3D ref vs Auto Scan 1-4
CCA	Median T1	0.97	0.76
	Median T2	0.92	0.85
ICA	Median T1	0.86	0.42
	Median T2	0.97	0.97

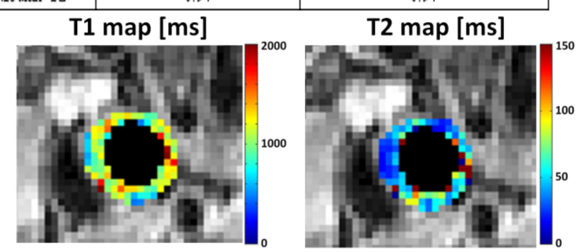

Figure 1: In vivo T1 and T2 map for carotid artery.

RESULTS:

Using manual vessel wall segmentation and registration with use of 3D ref, vessel wall T1 values were 1195 ± 247 ms, and T2 values 53 ± 13 ms, which is in line with published literature values. Table 1 reveals that automated vessel wall segmentation using tube fitting compared well with manual delineation using either the 3D ref data or the combined image. Table 2 reveals that registration using 3D ref as fixed image resulted in significantly higher T1,T2 fitting quality compared with the case when using fixed image from scan 1. Additionally table 3 reveals that not using the 3D ref results in a significant drop in correlation of T1- and T2 values compared to the optimal method using manual vessel wall segmentation and registration using 3D ref.

DISCUSSION AND CONCLUSION:

In this study, we investigated if the use of a separate 3D ref scan would improve T1,T2 mapping . We found that the quality of the combined image was sufficiently high for automated lumen and outer wall detection, However, the use of a 3D ref resulted in a more robust determination of T1,T2 values.

REFERENCES: [1] Biasiolli et al. J Cardiovasc Magn R 2013:15 [2] Coolen et al. ISMRM 2014; p115 [3] van's Klooster et al. Med Phys 2013:12 [4] van's Klooster et al. J Magn Reson 2012: 1