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Research Article

Vessel Wall Imaging of the Femoral Artery with a Dynamic T2 Preparation Pulse for Peripheral Arterial Disease Prediction

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Abstract

Aim: The aim of this study was to investigate whether vessel wall imaging using magnetic resonance imaging (MRI) with a T2 preparation pulse with dynamic implementation could accurately predict a proxy for atherosclerosis, carotid artery intima media thickness as measured by ultrasound. Ultrasound is still investigator dependent and a follow up of the femoral artery on its way to the foot and especially of the wall thickness is not possible due to anatomical reasons. Peripheral Arterial Disease (PAD) is a common disease in developed countries and it would be very helpful to have a predictive marker such as vessel wall thickness.

Methods: Five healthy volunteers and seven patients with known PAD underwent MRI of the femoral artery on a 1.5-T scanner with a SENSE-XL-Torso coil (Philips GmbH Market DACH, Hamburg, Germany) using TRANCE and a dynamic T2 preparation pulse afterwards. These measurements were compared with intima media thickness of the carotid artery as assessed by ultrasound.

Results: As measured by MRI, patients with PAD had significantly thicker vessel walls than healthy volunteers ($p < 0.01$). Carotid artery thickness matched femoral artery in patients with known PAD (Pearson $r = -0,99$, $p < 0,014$). Interobserver reproducibility was good (bias = -0.0088, 95% limits of agreement = -0.1089 to 0.09123), and ultrasound imaging results correlated closely to those from MRI (Pearson $r = -0.99$, $p < 0.027$).

Conclusion: Conducting MRI with a dynamic implementation of a T2 preparation pulse seems to be an adequate, non-invasive method to assess vessel wall thickness as a prognostic factor for atherosclerosis without using contrast agent.

Keywords: MRI; T2; Peripheral Artery Disease; Atherosclerosis

Introduction

Atherosclerosis is the most common disease in developed countries [1]. The onset of symptoms predicts a substantially reduced life expectancy [2], and atherosclerosis is often accompanied by comorbidities such as hypertension, diabetes and renal impairment. Peripheral Artery Disease (PAD), a disease in which plaque builds up the wall of an artery, is usually caused by atherosclerosis in the peripheral arteries from the accumulation of plaque, deposits of fats, cholesterol, and other substances, formations of which can grow large enough to significantly reduce blood flow through an artery. PAD is linked with coronary artery disease [3]. Clinical signs of a blockage of a peripheral artery are pain, cramps, changes in skin color, sores, or ulcers.

Endothelial dysfunction is a key factor in PAD development, and both environmental cardiovascular risk factors (e.g., smoking, diabetes, renal impairment and hypertension) and genetic background intersect to influence the extent of dysfunction, which triggers inflammation and degenerative vascular processes such as vessel wall thickening and stiffness that are caused by platelet and smooth muscle cell activation.

Indeed, others have observed a local association between endothelial dysfunction and intimal hyperplasia, which is predictive of five-year mortality rates for patients with PAD [4]. Because early detection allows an opportunity for earlier introduction of therapy, PAD patients will benefit from the development of predictive markers for risk assessment and early diagnosis. So far, ultrasound of the carotid arteries is state of the art for the non-invasive risk assessment of the formation for cardiovascular disease or atherosclerosis in general.

Basically, we conclude, if the intima-media thickness in ultrasound exceeds more than 0,07 cm the patient would be at risk for developing atherosclerosis. At present, DANTE FLASH is

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able to assess vessel wall imaging at 3T [5] and DANTE-SPACE was recently introduced to image deep vein thrombosis [6]. We developed a comparative imaging method to assess vessel wall thickness of the femoral artery as predictive marker for the development of PAD. Vessel wall imaging has been conducted by [7] using a flow-independent 3-D whole heart vessel wall imaging with an interleaved T2-preparation acquisition. The aim of the study was to investigate whether vessel imaging of the femoral artery with a dynamic T2 preparation pulse can provide predictive markers for atherosclerosis.

Methods

Study Population

Approval of the ethics committee of the University hospital Duesseldorf was obtained prior to commencement of recruitment. Five healthy volunteers and seven patients with known PAD took part in the study after written, informed consent was obtained. Magnetic Resonance Imaging (MRI) with a dynamic T2-preparation pulse was conducted, and intima media thickness was measured by ultrasound.

MR Protocol

Five healthy volunteers and seven patients with known PAD were scanned on a 1.5-T Philips Achieva scanner with a SENSE-XL-Torso coil (Philips GmbH Market DACH, Hamburg, Germany) using TRANCE (voxel size 0.83 × 0.83 × 1.2, flip angle 90°, TE 85ms, TR 750ms) and a dynamic T2 preparation pulse (voxel size 0.76 × 0.76 × 2.0, flip angle 30°, TE 4.4 ms, TR 1.38, slices 40) afterwards (Figure 2).

MR Analysis

Images were subtracted using MATLAB (release 2013a, version 8.0, Math works, Natick, MA, USA). A multiplicand factor of 1.8 was used for T2prep-ON images to achieve consistent blood signal subtraction. The subtraction factor was set to 1.8, because here we observed good contrast of the vessel wall compared to blood signal.

Image Analysis

For quantitative analysis, the targeted vessel wall lumen of the femoral artery and vessel wall images were reformatted along the major axis and analyzed using "Soap-Bubble" software (Release 5.0, Philips Healthcare, Best, NL) [8]. This semi-automatic software quantified length of the vessel lumen, proximal vessel diameter, and vessel sharpness. Two different cardiologists with more than five years of experience in MRI and ultrasound analyzed the images.

Measurements of Intima Media Thickness

Intima media thickness of the carotid artery was measured by ultrasound with semiautomated software (Vivid 7 Dimension, GE) in five healthy volunteers and seven patients with known PAD (Figure 4). Images were acquired in long axis views and short axis views of the arteria carotis communis, the arteria carotis interna, the arteria carotis externa and the arteria vertebralis on the left hand and right hand side native and afterwards with doppler ultrasound.

Afterwards, intima-media thickness was measured by two independent observers with at least five years of experience in ultrasound.

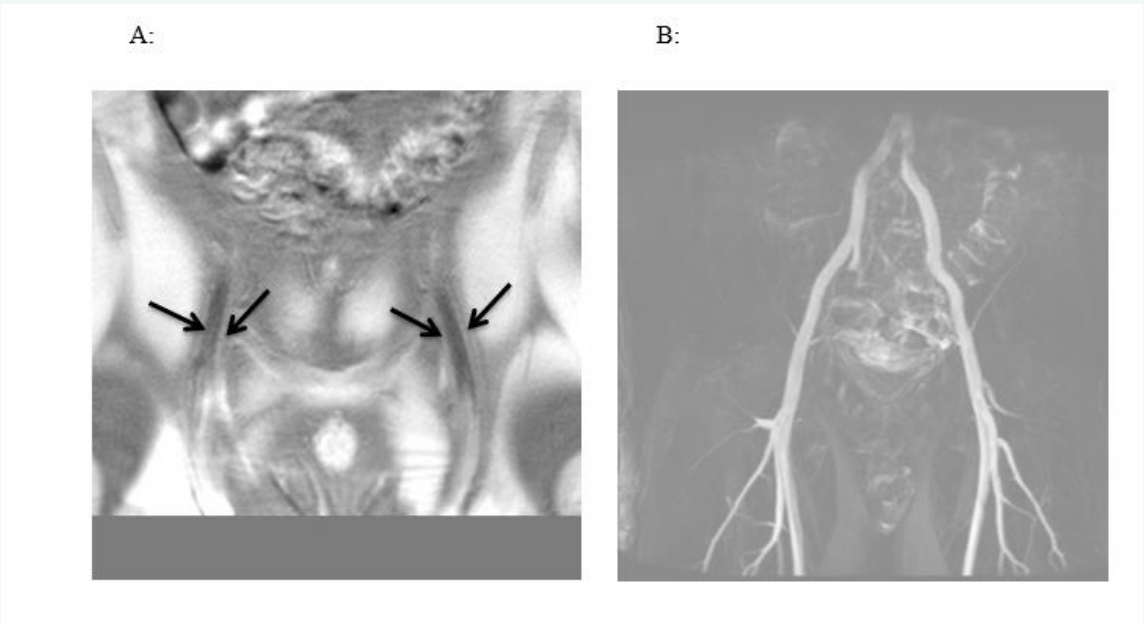

Figure 1 MRI of femoral artery.
A. Representative vessel wall imaging with the aid of dynamic T2 preparation pulse with weighted subtraction (B-1.8A).
B. Digital subtraction angiography of the limb artery (TRANCE) without application of contrast agent.

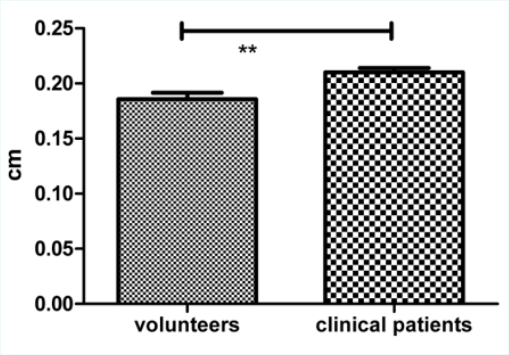

Figure 2 Vessel wall thickness of the femoral artery in healthy volunteers and clinical patients with known PAD (**p < 0.01).

Statistical Methods

Measurements were compared by Bland-Altman plots for normally distributed variables. *P*-values less than 0,05 were considered statistically significant. T-test was conducted for the comparison of vessel wall thickness in MRI of patients compared to healthy volunteers.

Results

Vessel wall imaging of the femoral artery using a dynamic T2 preparation pulse in MRI is possible without the application of a contrast agent (Figure 1). The imaged vessel wall of the femoral artery was significantly thicker in patients with known PAD than in healthy volunteers (Figure 2; $p < 0.01$). MRI vessel wall imaging is closely correlated with ultrasound measurements (Figure 3) (Pearson $r = 1.00$, $p < 0.014$). Ultrasound assessment of the carotid artery and MRI assessment of the femoral artery in clinical patients with known PAD were closely correlated (Pearson $r = -0.99$, $p < 0.027$) (Figure 4). Interobserver variability was low (Figure 5; bias -0.008, 95% limits of agreement from -0.108 to 0.09). Ultrasound assessment of the carotid artery and MRI assessment of the femoral artery in clinical patients with known PAD were closely correlated (Pearson $r = -0.99$, $p < 0.027$). Two fold analysis of the femoral artery delivered identical results ($p < 0.025$).

Discussion

In our study, we compared vessel wall imaging with MRI compared to ultrasound. First, we have used a dynamic T2 preparation pulse in MRI for the first time investigating vessel wall thickness in patients with known PAD compared to healthy volunteers. As expected, the imaged vessel wall of the femoral artery was significantly thicker in patients with known PAD than in healthy volunteers (Figure 2; $p < 0.01$). This MRI-sequence has already been introduced in an interleaved manner for whole heart acquisition [7] and for coronary artery imaging [8]. Little is published so far of vessel wall imaging of the femoral artery in MRI as predictive marker of atherosclerosis. For this reason, we compared vessel wall imaging of the carotid artery in patients with known PAD with ultrasound images of the femoral artery.

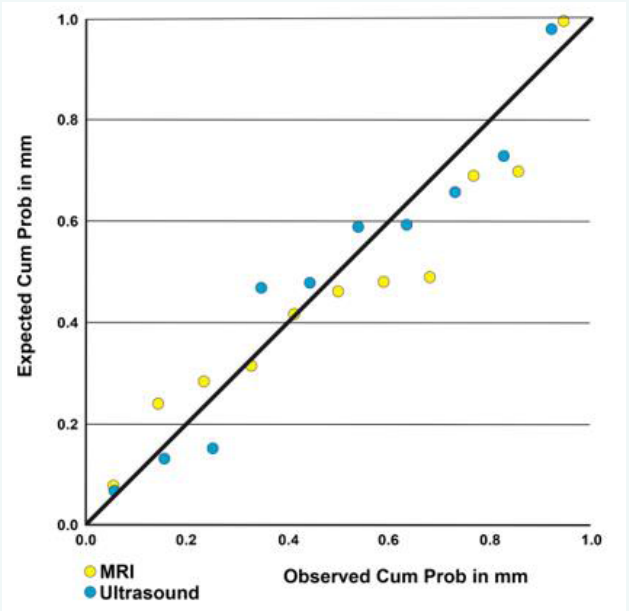

Figure 3 Correlation between MRI and ultrasound images of the femoral artery in patients with known PAD.

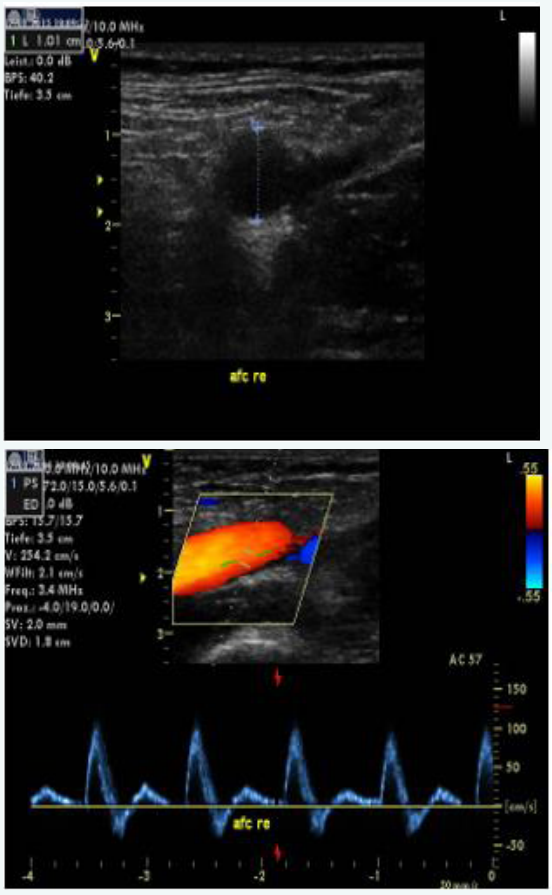

Figure 4 Representative ultrasound imaging of the carotid artery in healthy volunteers and patients with known PAD.

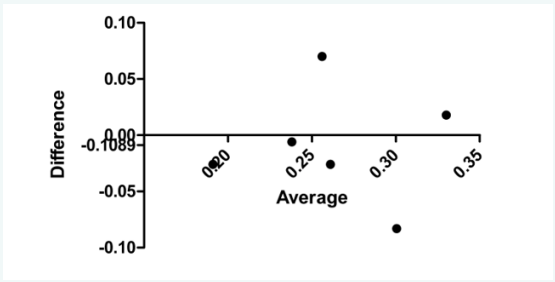

Figure 5 Bland-Altman plot of interobserver correlations of average measurement and difference between MRI measurements.

As expected, these results were closely correlated (Pearson r = -0.99, p < 0.027) [9].

In our study, we also compared our new MRI-technique with ultrasound. There was a good correlation seen of vessel wall imaging of the femoral artery compared to ultrasound (Pearson r = 1.00, p < 0.014). In recent studies, vessel wall imaging with the aid of MRI was used for the assessment of the carotid artery [10]. Applied T1-weighted three-dimensional imaging for the detection of vessel wall lesions in spontaneous symptomatic vertebrobasilar artery dissection [10,11] used optimization of improved motion-sensitized driven-equilibrium blood suppression for carotid artery wall imaging [11]. We have applied a dynamic T2 preparation pulse in MRI for the visualization of vessel wall with low interobserver variability (bias -0.008, 95% limits of agreement from -0.108 to 0.09). In our study we have shown for the first time, that our MRI vessel wall images correlated with the ultrasound method for vessel wall imaging of the femoral artery. Thus, vessel wall imaging of the femoral artery in MRI may serve as predictive marker of atherosclerosis. Further studies with larger patient numbers need to be done to confirm our assumption.

Conclusion

Conducting MRI with a dynamic implementation of a T2 preparation pulse seems to be an adequate, non-invasive method to assess vessel wall thickness as a prognostic factor for atherosclerosis without using contrast agent.

References

1. Nkomo VT, Gardin JM, Skelton TN, Gottdiener JS, Scott CG, Enriquez-Sarano M. Burden of valvular heart diseases: a population-based study. Lancet. 2006; 368(9540): 1005-1011. doi: 10.1016/S0140-6736(06)69208-8. PMID: 16980116.

2. Kaasenbrood L, Bhatt DL, Dorresteijn JAN, Wilson PWF, D'Agostino RB Sr, Massaro JM, et al. Estimated Life Expectancy Without Recurrent Cardiovascular Events in Patients With Vascular Disease: The SMART-REACH Model. J Am Heart Assoc. 2018; 7(16): e009217. doi: 10.1161/JAHA.118.009217. PMID: 30369323; PMCID: PMC6201391.

3. Wu J, Xia S, Kalionis B, Wan W, Sun T. The role of oxidative stress and inflammation in cardiovascular aging. Biomed Res Int. 2014; 2014: 615312. doi: 10.1155/2014/615312. Epub 2014 Jul 20. PMID: 25143940; PMCID: PMC4131065.

4. Sansone R, Stegemann E, Ozaslan G, Schuler D, Lukosz M, Rodriguez-Mateos A, et al. Early and late response-to-injury in patients undergoing transradial coronary angiography: arterial remodeling in smokers. Am J Cardiovasc Dis. 2014; 4(2): 47-57. PMID: 25006532; PMCID: PMC4082229.

5. Xie G, Zhang N, Xie Y, Nguyen C, Deng Z, Bi X, et al. DANTE-prepared three-dimensional FLASH: A fast isotropic-resolution MR approach to morphological evaluation of the peripheral arterial wall at 3 Tesla. J Magn Reson Imaging. 2016; 43(2): 343-351. doi: 10.1002/jmri.24986. Epub 2015 Jul 2. PMID: 26139414; PMCID: PMC4698243.

6. Zhuang G, Tang C, He X, Liang J, He Z, Ye Y, et al. DANTE-SPACE: a new technical tool for DVT on 1.5T MRI. Int J Cardiovasc Imaging. 2019; 35(12): 2231-2237. doi: 10.1007/s10554-019-01675-w. Epub 2019 Aug 24. PMID: 31446527; PMCID: PMC6856036.

7. Andia ME, Henningsson M, Hussain T, Phinikaridou A, Protti A, Greil G, et al. Flow-independent 3D whole-heart vessel wall imaging using an interleaved T2-preparation acquisition. Magn Reson Med. 2013; 69(1): 150-157. doi: 10.1002/mrm.24231. Epub 2012 Mar 5. PMID: 22392553.

8. Hussain T, Henningsson M, Butzbach B, Lossnitzer D, Greil GF, Andia ME, et al. Combined coronary lumen and vessel wall magnetic resonance imaging with i-T2prep: influence of nitroglycerin. Int J Cardiovasc Imaging. 2015; 31(1): 77-82. doi: 10.1007/s10554-014-0525-6. Epub 2014 Sep 9. PMID: 25200588.

9. Heinen Y, Stegemann E, Sansone R, Benedens K, Wagstaff R, Balzer J, et al. Local association between endothelial dysfunction and intimal hyperplasia: relevance in peripheral artery disease. J Am Heart Assoc. 2015; 4(2): e001472. doi: 10.1161/JAHA.114.001472. PMID: 25648609; PMCID: PMC4345872.

10. Natori T, Sasaki M, Miyoshi M, Ohba H, Oura MY, Narumi S, et al. Detection of vessel wall lesions in spontaneous symptomatic vertebrobasilar artery dissection using T1-weighted 3-dimensional imaging. J Stroke Cerebrovasc Dis. 2014; 23(9): 2419-2424. doi: 10.1016/j.jstrokecerebrovasdis.2014.05.019. Epub 2014 Aug 28. PMID: 25174566.

11. Zhu C, Graves MJ, Yuan J, Sadat U, Gillard JH, Patterson AJ. Optimization of improved motion-sensitized driven-equilibrium (iMSDE) blood suppression for carotid artery wall imaging. J Cardiovasc Magn Reson. 2014; 16(1): 61. doi: 10.1186/s12968-014-0061-5. PMID: 25160911; PMCID: PMC4145260.