Impaired Arterial Constriction During Reduced Shear can be Detected Using Phase-Contrast MRI: A New Technique for Assessing Endothelial Function

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Background

Dysfunction of arterial endothelium is one of the earliest physiological occurrences in atherosclerosis development [1]. Consequently, there is much interest in assessing endothelial function noninvasively in humans. The most common technique employs ultrasound to measure peripheral arterial dilation induced by hyperemia [2]. The increased shear causes dilation through the endothelial release of nitric oxide. An endothelial-dependent property that is underexplored is that arteries constrict during reduced shear. This is dependent on endothelin-1, a substance released by the endothelium that promotes atherosclerosis development [3]. Thus, measuring peripheral arterial constriction during reduced shear may provide useful additional information about endothelial function. Phase contrast magnetic resonance imaging (PCMRI) can measure arterial dimension and shear simultaneously. We investigated whether PCMRI could detect abnormal low-shear mediated constriction in a group with atherosclerotic risk factors.

Methods

The superficial femoral artery was studied in 20 men - 10 men with no risk factors aged 20-33 years, and 10 men with atherosclerotic risk factors including type II diabetics and older age, 52-69 years. A receiver coil was placed on the upper thigh, and an occluding cuff was placed distal to the receiver coil. A fixed cross-section of the artery was imaged before and during a distal occlusion. An ECG-gated PCMRI sequence was used, with 10 square cm field-of-view, matrix size 256 x 128, 3mm slice thickness, VENC 60 cm/sec in the S/I direction, TR 11.4 msec, 8 views per segment, and temporal resolution 182 msec. A user-independent algorithm was employed to locate the precise center of the arterial cross-section in the magnitude image by optimizing the correlation of datapoints in a radial plot. A smoothed average of the optimized radial plot of the data was calculated. The radius of the artery was defined using the full-width, half-maximum approach [4]. To calculate shear rate, velocity pixels of a radial plot near the lumen wall was fit by least-squares method to a parabola, with the assumption that blood flow velocity at the lumen wall is zero [5]. Shear rate was calculated as the slope of the velocity profile at the lumen-wall interface. Background correction was used in both the magnitude and phase plots. Shear rate and radius were averaged throughout the cardiac cycle.

Results

Figure 1 shows baseline magnitude and phase images at peak systole, and their corresponding radial plots for a typical control subject. The groups did not differ with respect to baseline radius or shear rate (p=NS). There was a nonsignificant trend of a smaller change in shear (-67±31 vs. -82±36 sec^{-1}, p=.17) and %change in shear (-49±21 vs. -59±11%, p=.10) from baseline to 2 minutes into occlusion in the older diabetics compared with controls. From baseline to 2 minutes into distal occlusion, radius decreased in the controls (3.24±.36 mm vs. 3.08±.32 mm, p=.0002) but not in the older diabetics (3.29±.32 mm vs. 3.30±.34 mm, p=NS). The %change in radius was -4.9±2.7% in the controls vs. 0.4±1.7% in the older diabetics (p<.0001).

Conclusions

1) Differences in peripheral arterial constriction during reduced shear can be measured using PCMRI. 2) Low-shear mediated constriction is impaired in older diabetics compared with a group without these risk factors. Measuring low-shear mediated peripheral vasoconstriction using PCMRI may add useful information to the noninvasive evaluation of arterial endothelial function.

References

1. Widlansky ME, Gokce N, Keaney JF Jr, Vita JA. *J Am Coll Cardiol*. 2003;42:1149-1160.
2. Celermajer DS, Sorensen KE, Gooch VM, et al. *Lancet.* 1992;340:1111-1115.
3. Spieker LE, Luscher TF, Noll G. *J Cardiovasc Pharmacol.* 2003;42:315-318.
4. Hoogeveen RM, Bakker CJ, Viergever MA. *J Magn Reson Imaging.* 1998;8:1228-1235.
5. Oyre S, Ringgaard S, Kozerke S, et al. *Magn Reson Med*. 1998;40:645-655.

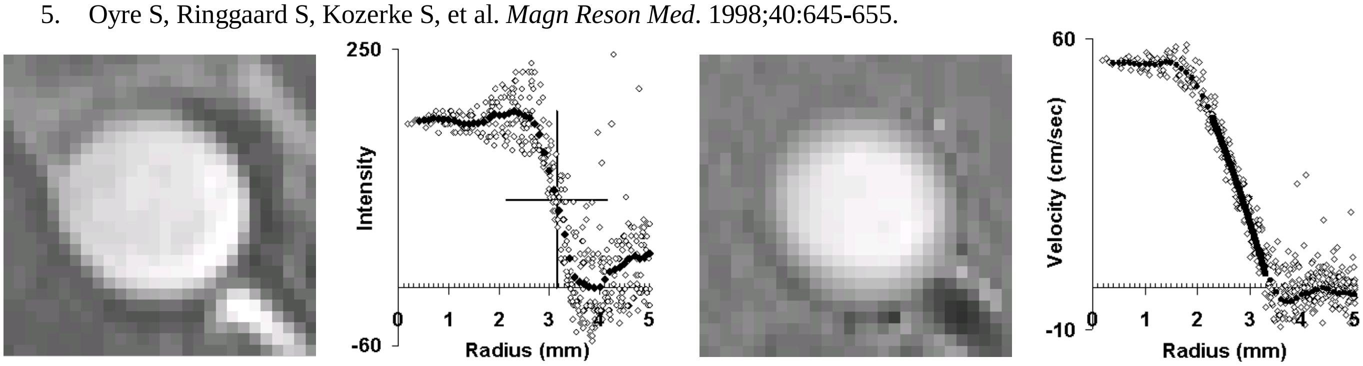

Figure 1A. Magnitude image at baseline during peak systole for a typical subject

B. Radial plot of magnitude pixel data, smoothed average, and full-width-half maximum location

C. Phase image

D. Radial plot of phase pixel data, smoothed average, and best-fit parabola segment