In Vivo Time Resolved Measurement of Vessel Wall Strain of the Ascending Aorta in Mice at 17.6T

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Introduction:

Characterization of arterial wall motion and strain delivers a direct measure of the function and viability of the vascular system [1]. Mouse models are increasingly used in basic research to investigate the functional consequences of gene-manipulation. However, at present there exists no adequate *in vivo* measurement method to investigate wall motion and strain on mice. We present a noninvasive black blood phase contrast subtraction method which allows temporally and spatially resolved strain measurement of the ascending aorta on mice.

Methods:

All measurements were performed on a Bruker Avance 750 spectrometer with a maximum gradient strength of 1.0T/m and a 20mm Bruker birdcage coil. Mice with body weights between 10 and 16g were anesthetized using 1.0 – 1.5 vol.% isoflurane inhalation. The cine MR imaging sequence consisted of an optimized segmented FLASH sequence with velocity compensation in all gradient directions. For in plane strain measurement a pre-saturation slab covering the entire left ventricle was applied before systole, allowing for reliable suppression of blood signal. Motion encoding was achieved by preparing the spin phase using a bipolar gradient which causes the moving spins to accumulate a velocity-dependent net phase with respect to stationary spins. Velocity was measured along all three directions using a four-point technique. The acquisition was ECG triggered and respiratory gated using a home-build ECG unit [2]. 15 frames perpendicular to the ascending aorta were acquired to cover a heart cycle for through-plane flow measurement and strain measurement, respectively. Software aided segmentation was applied to the acquired data. In plane velocity data for the aortic wall were corrected by subtracting rigid body motion and removing tangential components. The resultant data were used to compute an average radial velocity for the entire vessel at each point in time. The circumferential strain was calculated by [3]:

$$E_{\theta\theta} = \frac{1}{2}\left[\left(\frac{r}{R_0}\right)^2 - 1\right]$$

where R_0 gives the smallest vessel radius observed and r is the radius at any other measured point in time calculated from the radial velocity data by using a forward-backward integration scheme. Imaging parameters were: TE 2.8 ms, TR 6.0 ms, FOV 1.5x1.5 cm^2, slice-thickness 0.7 mm, resolution 59x59 μm^2, signal averages 6.

Results:

The measurement technique was validated on a rotating- and a tube-phantom yielding deviations of only 1.5 %. Figure 1 shows a Cine-FLASH image of the aortic arch used to navigate the slice of interest and the pre saturation slab. The aortic vessel wall was divided in 10 sectors. Averaged and corrected radial velocities for each sector are shown in figure 2 for one measured point in time. Circumferential strain calculations and through plane flow for one cardiac cycle are plotted in figure 3. Maximum strain was measured to be 0.25.

Conclusion:

In our study we have demonstrated that high field phase contrast MRI delivers motion encoded data at high temporal and spatial resolution allowing the quantification of time resolved aortic vessel wall strain. Since vessel wall radius was not calculated by spatial data, but by velocity data sub pixel displacements could be detected allowing for a higher accuracy in strain calculations.

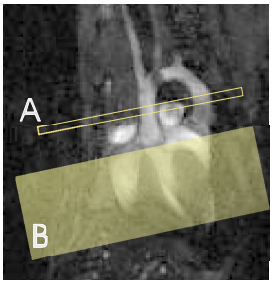

Figure 1

A: imaging slice
B: saturation slab

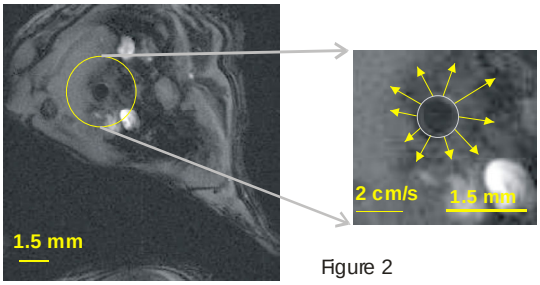

Figure 2

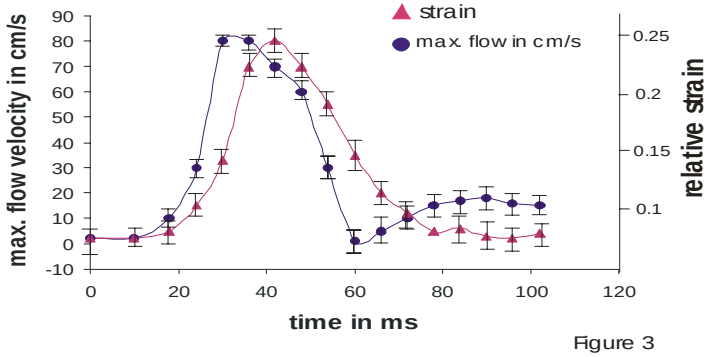

Figure 3

References:

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[2] Rommel E. et al., SMR 3rd Meeting [1995]; 938.
[3] Wedding KL et al. J Magn Reson Imaging [2002]; 15:418-428.

Acknowledgement:

This work was supported by
Glaxosmithkline Research & Development Limited.