In vivo measurement of local pulse-wave velocity in mice with MRI at 17.6 T

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Introduction:

Pulse wave velocity (PWV) is an important parameter for the evaluation of the arterial stiffness and cardiovascular risk. Several diseases such as hypertension and arteriosclerosis are associated with vascular remodeling and arterial stiffening. Mouse models of human diseases are increasingly used to investigate patho-physiological mechanisms of the cardiovascular system. We present a non invasive method to assess local PWV in the ascending and descending aorta of mice with MR-Microscopy at 17.6 T.

Methods:

Assuming a reflectionless and unidirectional waveform for the early systolic flow pulse, pulse-wave-velocity can be described as:

$$PWV = \frac{dQ}{dA}$$

where Q(t) denotes the volume flow through the aorta and A(t) is the cross-sectional area of the aorta (QA-method)[1]. To measure the time dependant parameters Q and A, a PC-Cine-FLASH-sequence with velocity compensation in all gradient directions was performed perpendicular to the vessel wall.

Through-plane-motion encoding was achieved by acquiring two additional datasets using bipolar gradients for the slice-encoding direction. Cross-sectional areas were extracted by manually segmenting the magnitude images obtained from the flow encoded datasets. To reduce eddy current artefacts, the bipolar flow encoding gradients were combined with the spatial encoding gradients such that the total gradient amplitudes were minimized for the slice encoding direction. The temporal resolution of 1ms at a repetition time of 5ms was achieved by acquiring five cine datasets with a time delay of 1ms between two subsequent datasets. Imaging parameters were: TE 2.1 ms, FOV 25×25 mm^2, slice-thickness 1.0 mm, resolution $98\times98\mu m^2$.

The total scan time was 10 minutes. Pulse wave velocity values were extracted by applying a linear fit to the function Q(A) for the data corresponding to the early systole. Local PWV-values were calculated for the (ascending) and the thoracic aorta respectively.

All measurements were performed on a Bruker Avance 750 spectrometer with a maximum gradient strength of 1.0T/m and a 27mm homebuilt TEM resonator. Mice with body weights between 30 and 35g were anesthetized using 1.5 vol.% isoflurane inhalation. ECG triggering and respiratory gating was applied for all MR measurements.

The gradient cooling unit was used to maintain the body temperature at 37°C. For temperature stability, it was necessary to work using a reduced gradient duty cycle, only examining the systole.

Results:

Figure 1 shows two representative magnitude images of the thoracic aorta. Aortic volume flow during the systole in the ascending aorta is shown in figure 2. The corresponding time course of the cross-sectional areas is depicted in figure 3. When evaluating the PWV as the slope of the linear function Q(A), a smoothing filter was applied to the time-dependant data Q(t) and A(t) (solid line in Fig. 2 and Fig. 3). Fig. 4 shows results of the PWV calculation for the ascending aorta. Mean pulse-wave-velocities for the ascending aorta were measured to be 2.8 m/s, mean pulse-wave-velocities for the thoracic aorta were measured to be 3.2 m/s.

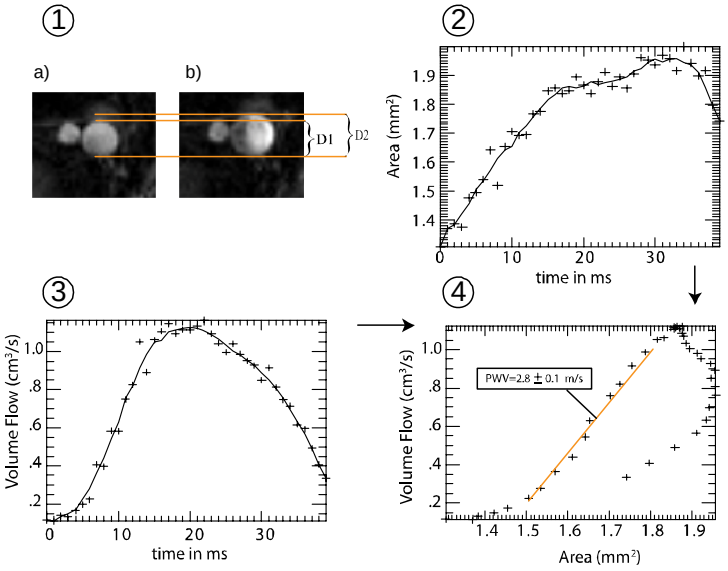

Fig.1 :Cross-sectional area of the thoracic aorta:
a) during diastole, b) during systole.
Fig.2 :Cross-sectional changes of the ascending aorta during systole.
Fig.3 :Volume Flow in the ascending aorta during systole.
Fig.4 :PWV-calculation as the slope of the flow-area relation during early systole.

Conclusion:

In this study, we have demonstrated the feasibility of high field MR microscopy to quantify local pulse wave velocity. The results are in a good agreement with PWV-values obtained by ultrasonic pulsed Doppler measurements [2,3]. A non-invasive method was provided to investigate local aortic stiffness, which will add to a better understanding of biomechanical aspects of intramural remodeling during arteriosclerotic lesion development.

References:

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