Retrospectively triggered local PWV Measurements in the murine aorta using a radial Sampling

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Introduction

The measurement of the pulse-wave-velocity (PWV) is an important tool for the estimation of arterial stiffness and enables the early diagnosis of cardiovascular risks. In recent studies prospectively triggered MRI methods have been developed to quantify the PWV in the mouse model [1]. Measurements in the murine aorta are usually conducted at a high magnetic field B_0 to provide higher SNR, which can cause problems with conventional triggering using ECG. For example, interferences with gradient eddy currents can reduce the quality of the trigger signal. In this work we present a retrospectively triggered measurement of the local PWV, which uses the centric k-space signal of a radial trajectory for navigation and is therefore independent of external triggering probes. The results are compared with a prospectively triggered radial PWV measurement.

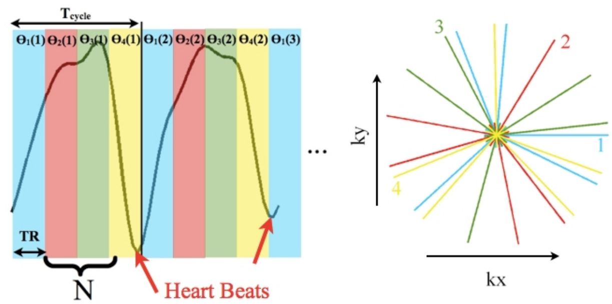

Figure 1: Left: K-space segmentation (displayed for N=4 segments).
Right: Radial Projections (shown for K=5 projections per segment)

Materials and Methods

All measurements are carried out on a 17.6T small animal system with a 1T/m gradient system and a 25mm birdcage coil. The abdominal aorta of healthy NMRI-Mice (Charles River) anesthetized with isoflurane was imaged in vivo. A Phase-Contrast (PC)-FLASH sequence was modified for velocity encoding with radial projections. For velocity measurements three encoding steps in slice direction (VENC=166.7cm/s) were acquired. With each encoding step n_Θ=48000 radial projections (80 readout points, echo position 10%, TE=1.3ms and TR=3.5ms, spatial resolution 150x150µm^2, slice thickness 1mm) were acquired without triggering. The total scan time was ≈ 8.5 minutes.

To achieve uniform k-space coverage for the reconstruction, the radial projections were divided into $N \approx T_{cycle}/TR$ interleaved segments (see Figure 1), where T_{cycle} is the length of an average heart cycle. Each segment consists of $K \approx n_\Theta/N$ projection angles. Starting with $\Theta_1(1)=0°$, the angles of each segment are calculated using $\Theta_n(i)=\Theta_{n-1}(K)+i\cdot\Delta\Theta$; i=1,…,K; n=1,…N, where $\Theta_{n-1}(K)$ is the last angle of the previous segment and $\Delta\Theta \approx 111.24°$ is the golden angle [2].

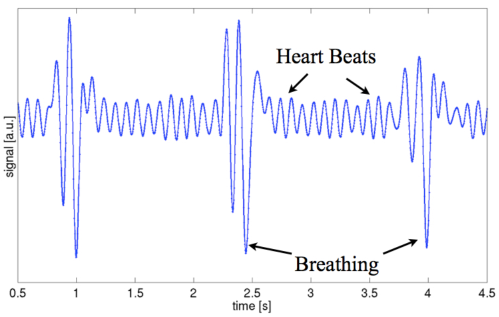

Figure 2: Navigator signal (shown for 4s oft the measurement).

For retrospective navigation the centric k-space signal of the radial projections was taken, which is strongly modulated by the change of blood signal in the aorta. High frequency disturbances and the low frequency modulation of respiratory motion were suppressed with a band-pass filter. With the Navigator signal, movie frames of the aortic motion were reconstructed using regridding with NUFFT [3]. For each heart cycle phase projections within a window of width ±TR/2 were accepted for reconstruction.

For PWV calculation the volume flow Q(t) through the arterial vessel and the cross-sectional area A(t) were determined using segmentation. The local PWV can be approximated as the slope of a linear fit (PWV_{loc}=dQ/dA) of the early systolic flow pulse (QA-method [4]).

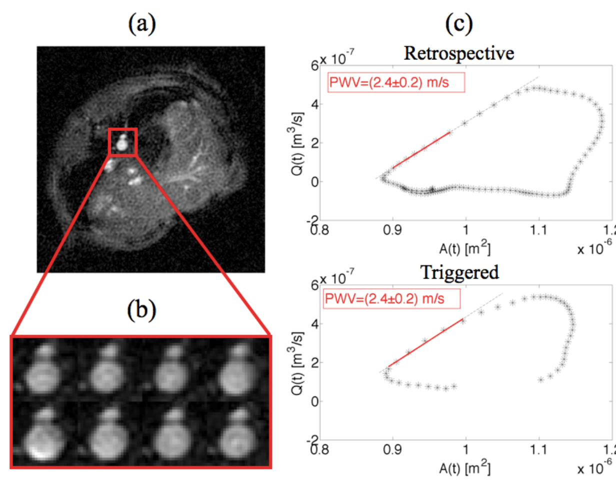

Figure 3: PWV Measurement:
(a) Reconstructed movie frame oft the abdominal aorta (resolution 150x150µm^2).
(b) Movie frames oft the aortic motion during the whole heart cycle.
(c) PWV-calculation using the QA-method [4]. Below: triggered. Above: retrospective.

Results

Figure 2 shows a section of the Navigator signal for the flow compensated measurement (M_1=0s/cm). The respiratory motion and the change of blood signal are clearly visible. Using the k-space Navigator 100 movie frames were reconstructed for the whole heart cycle phase (see Figure 3a and b). As comparison a prospectively triggered radial PC-Cine-FLASH measurement (spatial resolution 150x150µm^2, 42 movie frames, temporal resolution 1ms, total scan time ≈ 8 minutes) was acquired using a pneumatic measurement of the thoracic motion for triggering [5]. Figure 3c shows the determined volume flow Q(t) as a function of the cross-sectional area A(t) for both kinds of triggering. The PWV value obtained with the retrospective measurement is in good accordance with the value determined with the triggered acquisition.

Discussion and Conclusion

In the present study the retrospective PWV measurement with a radial sampling could be demonstrated to work. The Navigator signal provides a wireless triggering of the measurement, which makes this method very robust. The retrospective approach enables the monitoring of aortic motion during the whole heart cycle phase at high temporal resolution. However, the quality of the Navigator signal and the reconstructed images can be reduced by inhomogeneous magnetic fields and trajectory errors. To minimize these errors a high sampling bandwidth and a high echo asymmetry was used to provide short echo times. The trajectory errors were reduced by a gradient delay correction [6].

References

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