Highly accelerated in vivo measurement of local pulse wave velocity in mice using a k-t BLAST QA-method

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Introduction: Local elastic properties of the murine aortic vessels such as the pulse-wave-velocity (PWV) can be calculated using PC-MRI to quantify simultaneously the blood-flow (Q) and the cross-sectional area pulse (A) (QA-method) [1]. Of paramount interest however is a short total measurement time in order to perform the data acquisition during a constant cardiac cycle. To quantify the PWV the measured Q and A pulses have to undergo a frequency low pass filtering in final post processing steps. We present a method which substitutes temporal low pass filtering by temporal undersampled data acquisition followed by a k-t BLAST reconstruction with the benefit of an almost 10 fold acceleration of data acquisition without compromising the PWV calculation.

Methods:

To measure the time course of the blood volume flow Q and the cross sectional area A, a high resolution PC-Cine-FLASH sequence was performed perpendicular to the abdominal aorta with through plane flow encoding. The local pulse wave velocity PWV was estimated using the QA-method (i.e. PWV=dQ/dA for early systolic time points). For k-t BLAST reconstruction we extracted a temporal undersampled (af=10; lattice sampling pattern as described in [2]) dataset from a fully sampled PC-MRI-data (supplemented by a training dataset with 8 center k-space lines). The post processing for the undersampled data is described in figure 1. After transferring the folded 3D dataset (x,y,t) into the xf-space the data were unfolded by using a low-resolution training dataset according to the k-t BLAST reconstruction scheme [2].The resolution of the training dataset (i.e. the number of center-k-space lines) regulates the high-temporal frequency suppression in the reconstructed images (by spatially averaging high frequency effects) acting like a low pass filter on the final QA-plots. By adjusting the number of center k-space-lines to 10 in the training dataset we could mimic the effect of the originally applied low pass filters on the QA-data. Thus the total measurement time could be reduced by a factor of almost 10 without compromising the accuracy of the PWV calculation. All in vivo measurements were performed on a Bruker Avance 750 spectrometer (17.6T) with a maximum gradient strength of 1.0T/m and a 27mm homebuilt TEM resonator. C57Bl6 mice at the age of 8 months were anesthetized for MR-measurements using 1.5 vol.% isoflurane inhalation. ECG triggering and respiratory gating was applied for all MR measurements. Imaging parameters were: TE 2.1 ms, FOV 25×25 mm^2, slice-thickness 1.0 mm, resolution 98×98 μm^2
, temporal resolution of fully sampled data-sets: 1ms [1].

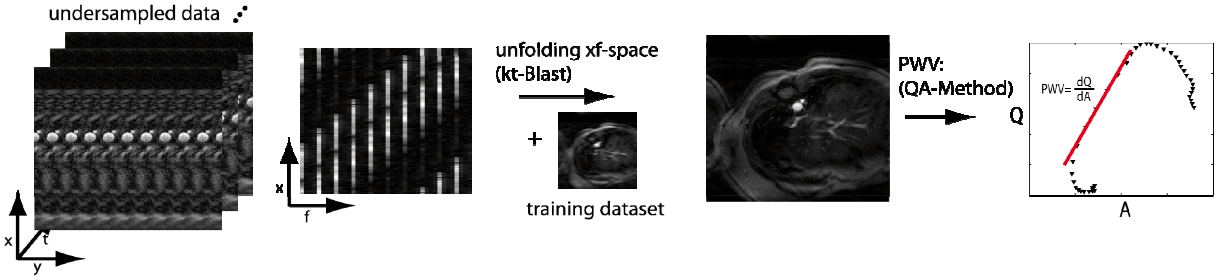

Fig.1: Post processing steps for the k-t_BLAST QA-reconstruction fully sampled data set.

Results: Figure 2(a-c) shows the PWV-evaluation of a fully sampled data set. In figure 2c the vulnerability of the QA data due to high-temporal-frequency noise can be seen. After applying frequency low pass filters the PWV data can be calculated as the slope of the data of the early systolic Q and A-pulses. When evaluating 10 fold undersampled data the QA plot indicates no need for further filtering and reveals almost identical PWV values as obtained with the fully sampled data (figure 2 d-e).

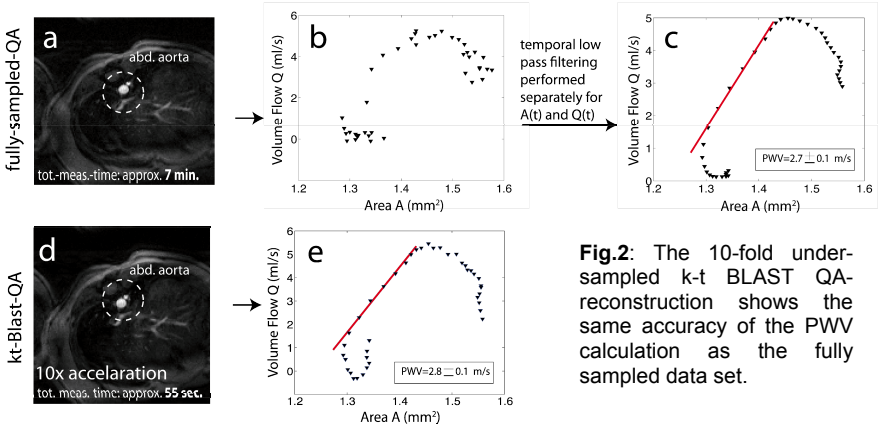

Fig.2: The 10-fold under-sampled k-t BLAST QA-reconstruction shows the same accuracy of the PWV calculation as the fully sampled data set.

Conclusion:

The presented method allows the local PWV-acquisition in less than 1 min. in mice. Thus enabling for the first time to examine the distribution of local elastic properties by applying the method at different locations along the aortic vessel during one experiment. Knowing the distribution of elastic properties in aortic vessels would be of great value in the atherosclerotic research. The presented method is also not limited to small animal studies. All human MR-studies examining mechanical vessel wall parameters based on low frequency changes (such as the vessel wall compliance, PWV, elasticity) would benefit from the stability and significant time reduction.

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References:

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