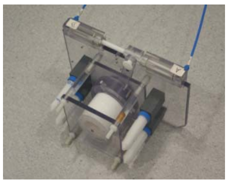
Applicability of k-t BLAST, k-t SENSE, k-t PCA and k-t PCA/SENSE for tissue phase mapping in a heart phantom at 3T

Anja Lutz[1], Sebastian Kozerke[2], Jan Paul[1], Michael Schmucker[1], Axel Bornstedt[1], G Ulrich Nienhaus[3], Wolfgang Rottbauer[1], and Volker Rasche[1]

[1]*University Hospital of Ulm, Ulm, BW, Germany,* [2]*ETH Zürich, Institute for Biomedical Engineering, Zürich, Switzerland,* [3]*Karlsruhe Institute of Technology, Karlsruhe, BW, Germany*

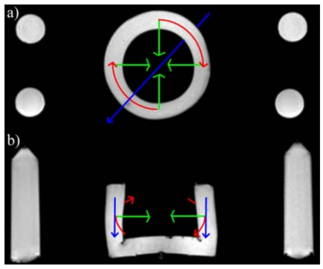
Fig. 1: The Heart Phantom



Objective: Quantification of cardiac mechanics by tissue phase mapping (TPM) is supposed to provide an improved understanding of cardiac motion and to enable a detailed assessment of myocardial diseases such as cardiac asynchrony and DCM. A major limitation of TPM in clinical routine is the related long acquisition time.

The objective of this study is to investigate the impact of different acceleration techniques (k-t BLAST, k-t SENSE, k-t PCA and k-t PCA/SENSE) on the accuracy of the velocity quantification in a beating heart phantom.

Fig. 2: MR images of the heart phantom. a) short axis view. b) long axis view. The blue, green and red arrows show the moving direction in longitudinal, radial and circumferential direction.

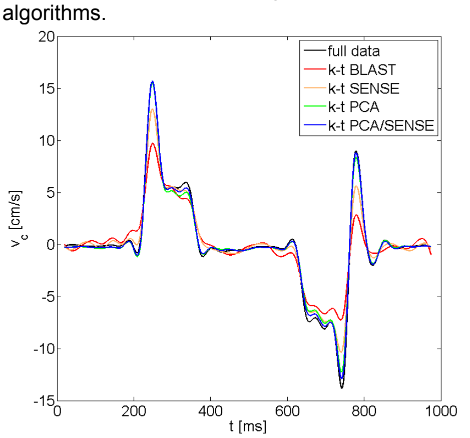


Materials and Methods: The beating heart phantom consists of a beating PVA cylinder, which was actuated by pressured air [1] (Fig.1). Imaging was performed on a 3T whole body MR scanner (Philips, Best, The Netherlands) with a 32 channel phased array coil. 8 'short axes' parallel to the bottom of the heart phantom were investigated in order to have different motion patterns in each slice. A velocity encoded triggered gradient echo sequence was performed with the following parameters: T_R/T_E = 6.2ms/3.9ms, α = 15°, FOV = 290x290mm^2,slice thickness= 8mm, in-plane resolution =2x2mm^2, 3 k-lines per segment + one startup echo, acquisition window = 98% of the RR interval, phase interval = 25.1ms and VENC = 30cm/s. After data acquisition, the data were undersampled in k-t space according to the k-t BLAST undersampling pattern [2] with undersampling factors R = 2-8 and n_{tr} = 11 training profiles. Afterwards, the data were reconstructed by either k-t BLAST [2], k-t SENSE [2], k-t PCA [3] or k-t PCA/SENSE [3]. The obtained anatomical and velocity encoded images were post-processed as follows: The radial (towards the center of the PVA-ring), longitudinal (towards the bottom of the phantom) and the circumferential velocity (clockwise direction) were calculated for each slice and each acceleration factor (Fig. 2). Afterwards, the resulting velocities over time curves were compared to those curves obtained by the full data acquisition. The following parameters quantify the applicability of the specific reconstruction algorithms to obtain the true velocity over time-curves: The velocity range Δv, the correlation coefficient and the normalized root mean square deviation (nRMSD).

The quality of the applied reconstruction approach was assessed according to the expected reproducibility of the technique. Velocity over time curves were assumed to not differ substantially from the gold standard (full data reconstruction), if no significant differences in the velocity ranges, correlation coefficients higher than 0.95, and nRMSD ≤ 0.05 for each computed velocity direction were obtained.

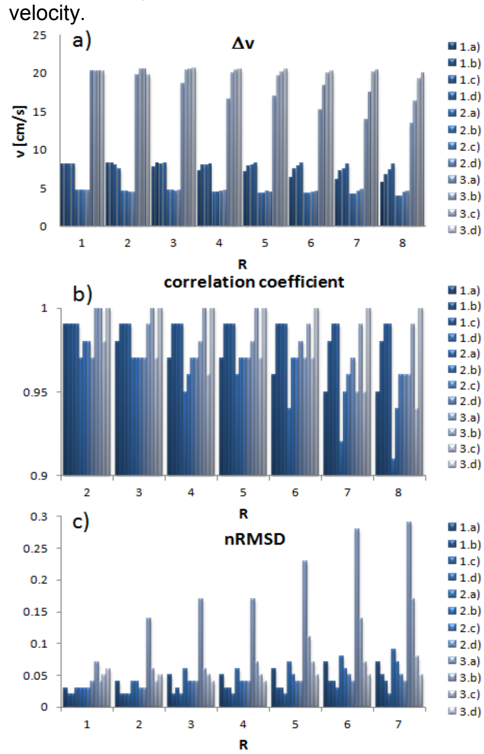
Results: Fig.3 shows the circumferential velocity over time curves exemplary for R=8. Visually k-t PCA/SENSE performs best followed from k-t PCA, k-t SENSE and k-t BLAST. Fig. 4 contains a chart diagram of the velocity range, correlation coefficient and nRMSD. No significant difference from the gold standard was fulfilled for k-t SENSE (R=2), k-t PCA (R = 3-5) and k-t PCA/SENSE (R = 3-8).

Fig. 3: Circumferential velocity over time curves without acceleration and for an acceleration factor of R=8 for all investigated reconstruction algorithms.



Conclusion: In this study, different reconstruction algorithms were tested in phantom data in order to compare the applicability of different reconstruction algorithms to accelerated TPM data. For high acceleration factors, the use of sensitivity maps and principal component analysis improved the quality of velocity data.

Fig. 4: Velocity range, correlation coefficient and nRMSD for different acceleration factors R with reconstruction algorithm k-t BLAST (a), k-t SENSE (b), k-t PCA (c) and k-t PCA/SENSE (d). 1 corresponds to the longitudinal velocity, 2 to the radial velocity and 3 to the circumferential velocity.



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