SIMPLE MOTION CORRECTION STRATEGY REDUCES RESPIRATORY-INDUCED MOTION ARTIFACTS FOR K-T ACCELERATED CMR PERFUSION IMAGING

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TARGET AUDIENCE: Clinicians and researchers interested in motion corrected k-t accelerated cardiac perfusion imaging.

INTRODUCTION: CMR perfusion imaging has significant advantages for cardiac stress testing. However, current clinical techniques are limited to acquire 3 or 4 slices during a heartbeat with limited spatial and temporal resolution. K-t accelerated techniques such as k-t SENSE[1] and k-t PCA[2, 3] utilize the temporal correlations in the dynamic data to constrain image reconstruction. Although these techniques can achieve high acceleration factors, they are sensitive to respiratory-motion induced artifacts. Similarly, compressed-sensing techniques[4] enable highly accelerated acquisition, but they are also sensitive to respiratory motion, which causes image blurring. Navigator gating based techniques[5] have been used primarily for free breathing-coronary imaging, but they prolong image acquisition, require dedicated setup, and are prone to errors resulting from the difference between diaphragmatic motion and cardiac motion. Self correction strategies[6] extract the motion information from the acquired data, and then use this motion information during image reconstruction. However, repeated application of non-rigid registration operators can result in image degradation due to spatial interpolation in each iteration. In this work, we propose a simple robust respiratory motion compensation strategy for k-t accelerated CMR perfusion imaging to selectively correct respiratory motion of the heart based on linear k-space phase shifts derived from rigid motion registration of a heart ROI.

METHODS: Multi-slice 2D saturation-recovery first-pass gadolinium-enhanced data were collected from 10 patients on a 1.5T scanner using a 5-channel phased-array RF coil. For each patient, 3 short-axis slices were acquired per heartbeat for 50-70 heartbeats. The 4x accelerated variable density k-t sampling pattern fully sampled the central 10 phase-encoding lines while the outer 30 phase-encoding lines were undersampled following a Poisson disk distribution. Other parameters included: FOV 320mm, Matrix 160x160, 40 phase-encoding lines/image, spatial resolution 2mm x 2mm, slice thickness 8mm, TR 2.4ms, saturation recovery time 100ms, acquisition window per slice 96ms.

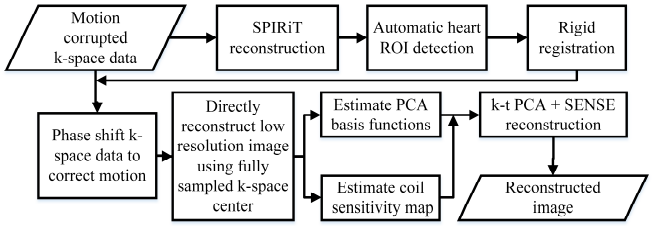

Fig. 1 Reconstruction Pipeline

The reconstruction pipeline is illustrated in Fig. 1. We first reconstructed images at each time frame using SPIRiT. A rectangular ROI containing the heart was automatically detected, and rigid registration of this heart region was used to derive the linear phase shifts in the x and y direction that were applied to the acquired k-space data for motion correction (MC). The final image reconstruction was performed using k-t PCA on the linear phase-shifted k-space data. To demonstrate the effectiveness of the motion compensation strategy, we reconstructed the data using k-t PCA without motion compensation for comparison. The reconstruction was repeated using k-t SLR[4] with and without motion compensation to demonstrate the performance of this motion compensation strategy for CS reconstruction.

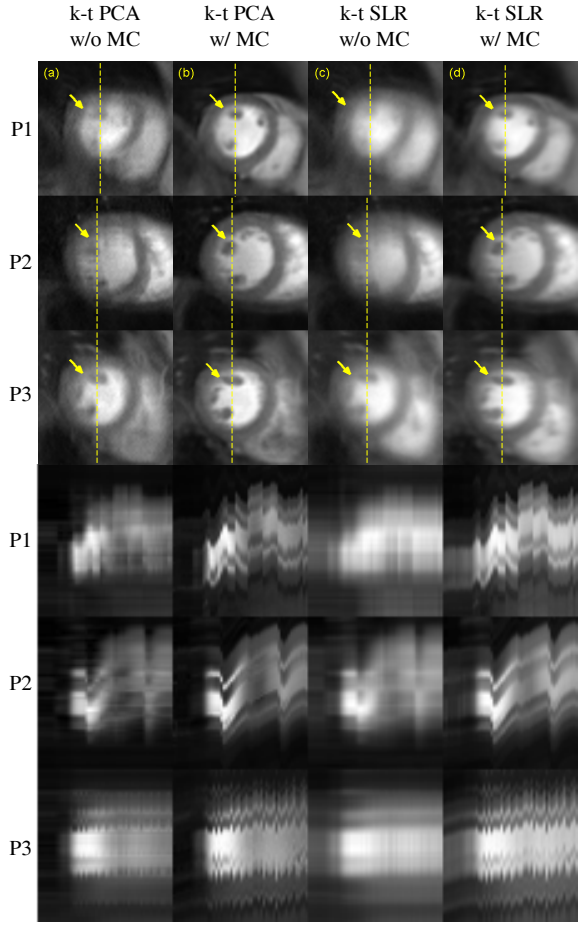

Fig. 2 k-t PCA and k-t SLR reconstructions without (a, c) and with (b, d) motion compensation for 3 patients P1, P2 and P3. The top 3 rows show the reconstructed images at one time frame and the bottom 3 rows show the x-t profiles corresponding to the dash lines in the reconstructed images.

RESULTS: Fig. 2 shows the k-t PCA reconstructed images without (a) and with (b) motion compensation and k-t SLR images without (c) and with (d) motion compensation from 3 patients with significant respiratory motion during image acquisition. From the images shown in the top 3 rows in Fig. 2, it is clear that the reconstructed images using both k-t PCA and k-t SLR with our motion compensation strategy have much sharper edges and clearly delineated structures within the ventricle that are not well visualized in the non-motion compensated images. From the x-t profiles shown in the bottom 3 rows in Fig. 2, it is clear for both patient P1 and patient P2 that the motion artifacts are significantly reduced by our motion compensation strategy without over-smoothing the temporal signals despite considerable respiratory motion during image acquisition. The respiratory motion of Patient P3 was rapid and shallow during acquisition but the improvement in image quality is evident in the image reconstruction and in the x-t profiles of the motion corrected images.

DISCUSSION: Our simple and robust motion compensation strategy is able to remove the respiratory motion artifacts in the heart region at the expense of some motion degradation of anatomy remote from the heart. This property makes it very suitable for CMR perfusion imaging where the myocardium is the only region of interest. In addition, our strategy only phase-shifts the k-space data once and therefore avoids the spatial blurring resulted from the repeated application of non-rigid registration operators during conventional iterative motion compensation.

CONCLUSION: Our simple and robust rigid motion compensation strategy greatly reduces motion artifacts and improves image quality for the standard k-t acceleration (k-t PCA) and CS (k-t SLR) techniques in setting of significant respiratory motion.

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