Evaluation of k-t SENSE for cardiac imaging of rats at 9.4T

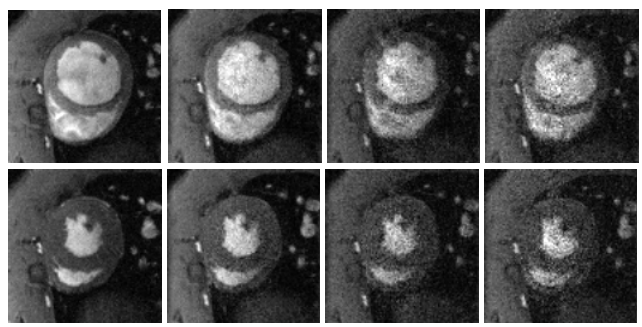
A. N. Price[1], K. K. Cheung[1], S. J. Malik[2], and M. F. Lythgoe[1]

[1]Centre for Advanced Biomedical Imaging, UCL Institute of Child Health, University College London, London, United Kingdom, [2]Imaging Sciences Department, Hammersmith Hospital Campus, Imperial College London, London, United Kingdom

Introduction: In recent years parallel imaging and dynamic undersampling have become routinely available in clinical cardiac MRI. Unfortunately, these techniques have been slow to translate to the pre-clinical setting. However, a recent study has reported on the retrospective evaluation of using TGRAPPA on rat cine data [1], and another on the implementation of k-t SENSE [2]. k-t SENSE uses both coil encoding and the inherent redundancy associated with time series data and thus can be used to successfully reconstruct data undersampled by factors higher than the number of receive coils. In this abstract we present a full implementation and quantitative evaluation of up to 5x dynamically undersampled data using a four-channel array coil on a 9.4T experimental system. Left ventricular ejection fraction and stroke volume were calculated from fully sampled and accelerated data in order to evaluate the accuracy of the technique.

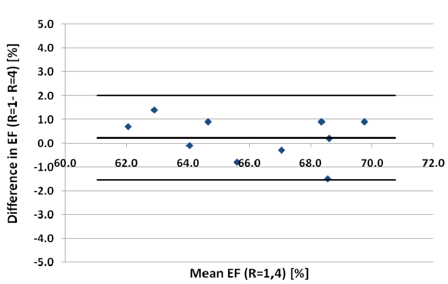
Methods: Male Wistar rats (n=10), weighing 300-370g, were anaesthetised with sodium thiopentone (i.p.) and imaged on a 9.4T Varian (VNMRS) system using a 72mm de-tuneable transmit coil and a four-element phased array receive coil (Rapid Biomedical GmbH). Cine cardiac data was acquired using a modified double gated spoiled gradient echo sequence (TE/TR=1.3/6-8ms, 20 cine frames, 200µm in-plane resolution, N_{PE}=192 (R=1), slice thickness=1mm, NA=1). Complete short-axis stacks (typically 15 slices) were acquired individually using reduction factors (R)=1,2,4,5 (relating to N_{PE}=192,96,48,38 respectively). In addition, 16 lines of training data were acquired separately for k-t SENSE, and coil sensitivity maps were estimated from the time averaged data. Phase encoding (and therefore undersampling) was performed in the left-right direction, in which the variation in sensitivities of the coil elements was greatest. Undersampled data sets were reconstructed using k-t SENSE in Matlab (Mathworks) and compared to the fully sampled images. Left ventricle ejection fraction (EF) and stroke volume (SV) for all data were calculated from the complete image sets using Segment (http://segment.heiberg.se/).

Results and Discussion: Figure 1 shows representative end-diastolic and end-systolic frames from k-t SENSE reconstructed cine data (R=2,4,5) alongside the separately acquired fully encoded images (R=1). The reduced sampling leads to an intrinsic loss in SNR of $\sqrt{R}$, however, k-t SENSE reconstruction mitigates this with inherent temporal filtering, limiting the loss of SNR in regions not requiring full temporal bandwidth. Graph 1 shows a Bland-Altman plot of the difference in LV ejection fraction between the measurements acquired using R=1 & 4, demonstrating an absolute difference in EF of only 0.23±0.91% (mean±SD). Graph 2 shows a similar plot for the stroke volume where the difference here is 16.5±15.5 µl. Although the EF measurements for R=4 show excellent agreement with the fully sampled data, there is a slight underestimation (4.9%) in the SV measurement. This becomes more evident at R=5, which can been seen in Graph 3 along with a comparison of the relative differences in EF and SV for R=2,4,5 data. It is likely that other functional measures such as LV mass will not yield high correlation due to the increasing difficulty in delineating the epicardial border where SNR and CNR are already inherently low using a sequence optimised for high blood-myocardium contrast.

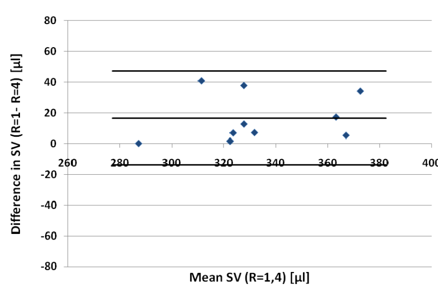


R=1 **R=2** **R=4** **R=5**

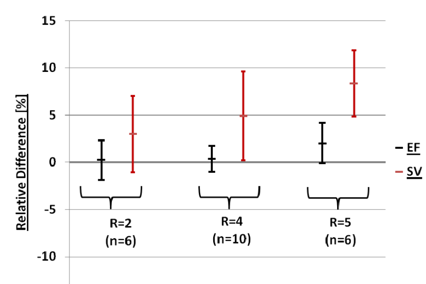
Figure 1. Representative end-diastolic (top) and end-systolic (bottom) images from k-t SENSE reconstructed data acquired using reduction factors of R=1,2,4,5.



Graph 1. Bland-Altman plots of absolute difference in EF between R=1 minus R=4 data. Lines represent mean difference ± 1.96 SD.



Graph 2. Bland-Altman plots of absolute difference in SV between R=1 minus R=4 data. Lines represent mean difference ± 1.96 SD.



Graph 3. Comparison between R=1 and R=2,4,5 reductions on the relative EF and SV. Plots represent the relative mean ± 1 SD.

Conclusion: k-t SENSE can be used to acquire accurate functional cardiac data with reduction factors in excess of 4x using a four-element array coil. Although higher acceleration has been demonstrated, inherent SNR levels limit the resultant image quality and accuracy of particular functional parameters. In this implementation the acceleration results directly in scan time reduction for rapid assessment of cardiac function, where we have demonstrated that LV ejection fraction can be accurately assessed at 0.2 x 0.2 x 1mm resolution within 2-3 minutes. However, the real benefit of this increased spatiotemporal resolution could be to improve techniques such as dynamic contrast imaging in small animal models, where spatial and temporal resolution are limiting factors.

References: [1] Schneider et al, MRM 59:636-641(2008). [2] Price et al, Proc. ESMRMB 2008 #765.