

Quantification of myocardial perfusion: A study of the number of readouts required for a radial acquisition with TV-constrained reconstruction

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Introduction: The use of dynamic contrast enhanced (DCE) MRI for quantification of myocardial blood flow is gaining clinical credence. Quantitative estimates of perfusion require knowledge of the contrast concentration in the arterial input function (AIF) and in the myocardial tissue curves. However the ability to track the rapidly changing contrast concentration is one of the major hurdles in DCE MRI. Compressed sensing (CS) methods are being used to improve perfusion scanning but have not been evaluated for quantifying cardiac perfusion. The ability to rapidly acquire and reconstruct images makes CS type methods ideal to track the uptake and washout of a contrast agent and thereby quantify myocardial blood flow (MBF) and myocardial perfusion reserve (MPR). In particular, the estimation of MBF and MPR using undersampled radial acquisition with CS [1] has not been studied systematically. In this article we compare the estimates of MBF and MPR using undersampled radial acquisition and those using validated 72 ray radial acquisitions [2].

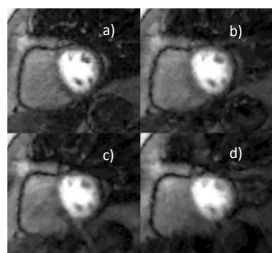


Figure1. Single timeframe from one dataset reconstructed using a) 72 rays b) 24 rays c) 18 rays d) 10 rays

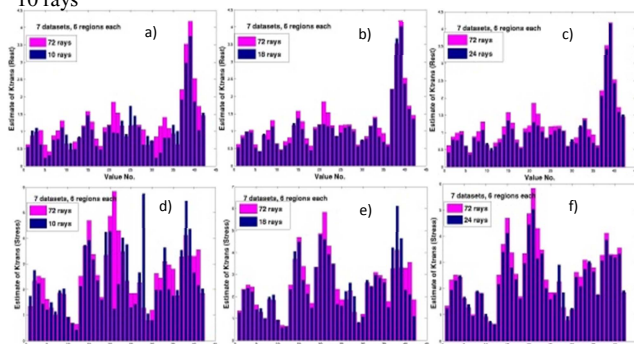


Figure3. Histogram showing the distribution of K^{trans} estimated by reconstructions using Top] Rest a) 10rays b) 18 rays c) 24 rays. Bottom] Stress a) 10 rays b) 18 rays c) 24 rays compared with reconstructions using 72 rays

for the rest and stress acquisitions.

Results/Discussions: Figure1. shows a timeframe from a single dataset reconstructed using 72 rays, 24 rays, 18 rays and 10 rays. It can be seen that the images are identical with blurring in case of the 10 ray reconstruction. Figure2. shows the tissue curves for a single dataset reconstructed as mentioned before. A good match is seen between tissue curves using 24, 20, 18 and 72 rays. The tissue curve using 10 rays for reconstruction shows large deviations from truth. Figure3. shows the distribution of the K^{trans} parameter estimated for the rest and stress acquisition using the radially undersampled datasets. A similar distribution of the K^{trans} for all of the reconstructions except the 10 ray reconstruction points towards the ability of the undersampled datasets to accurately quantify myocardial perfusion. Figure4. shows the plot of MPR reserve using the undersampled datasets versus the MPR using the 72 ray dataset. The figure shows a tight distribution around a line with unity slope and zero intercept. However, errors in estimation of MPR using 10ray reconstruction are evident from the larger spread in the MPR estimates for the same. Figure5. shows the Bland-Altman plot between the K^{trans} for 72 ray and 18 ray datasets showing that 18 ray reconstruction gave similar perfusion estimates as the 72 ray reconstruction. When only 10 rays were used, however, significant errors were introduced. This work shows that using undersampled radial acquisition with as few as 18 rays can quantify myocardial perfusion, giving perfusion and MPR estimates similar to much slower 72 ray acquisitions. Such rapid acquisition allows greater cardiac coverage as well as enabling other approaches such as recently proposed ungated acquisition techniques.

References: [1] Adluru, G., et al. J Magn Reson Imaging, 2009. 29(2): p. 466-73. [2] Kim, T.H., et al. J Cardiovasc Magn Reson, 2010. 12: p. 45.

Methods: Perfusion data were acquired on a 3-Tesla magnet (Siemens Trio or Verio) using a saturation recovery radial turboFLASH sequence in 7 volunteers. 72 rays per slice were acquired. The acquisition parameters were TR = 2.6 ms, TE = 1.14 ms, flip angle 14°, 2.3 X 2.3 X 8 mm voxel size. 2-3 slices were acquired, each after a separate saturation pulse. All of the perfusion images were acquired during shallow breathing. Perfusion imaging was first done at rest, then during adenosine infusion (140 μ g/kg/min). A 5 cc/s injection of Gd-BOPTA was used for each perfusion sequence, with doses of 0.02mmol/kg at rest and 0.03mmol/kg at stress.

Images were reconstructed using a CS spatio-temporal TV reconstruction method [1]. A single mid-ventricular slice was selected for analysis. Images from the 72 ray acquisition were considered as the ground truth. Undersampled acquisitions were created by selection of subsets of the 72 ray data. 24 rays, 20 rays, 18 rays and 10 rays were simulated from the 72 ray acquisition in a golden-ratio pattern. The undersampled datasets were reconstructed individually using the CS-TV method, with weights adjusted for the number of rays. Automatic registration with some manual adjustments was performed on the 72 ray dataset. Further processing involved segmenting the myocardium. This was done automatically with some manual corrections. The shifts and the segmentation from the 72 ray dataset were also used for the undersampled datasets to prevent any intra-observer bias. Tissue curves and the AIF curves were recorded and the pre-contrast signal was subtracted off. This was followed by fitting the data to a two-compartment model to report the K^{trans} parameter. The processing steps followed were identical

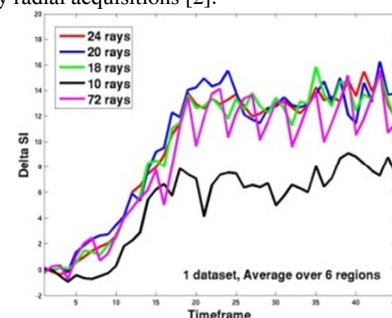


Figure2. Tissue curves from one dataset averaged over 6 regions. Different colors represent different no. of rays used for reconstruction

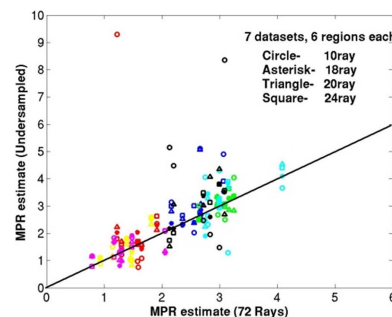


Figure4. MPR estimates using undersampled reconstructions vs. MPR estimates using 72 ray reconstruction.

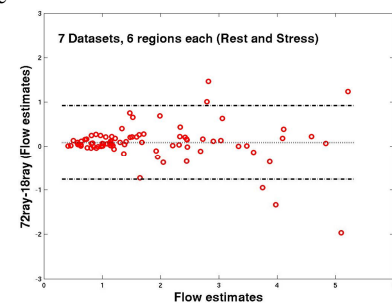


Figure5. Bland-Altman plot of flow estimates for 72 ray and 18 ray reconstructions