AIF Determination for Quantitative Myocardial Perfusion Imaging Using a Model Based Reconstruction of Radially Acquired Data

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Introduction:

Quantitative myocardial perfusion imaging depends on a precise determination of the arterial input function (AIF). However, for typical doses of contrast agent and recovery times TI, the AIF determination is hampered by saturation effects. In general, the effects can be overcome by an additional measurement with low contrast agent bolus (1, 2), or by performing the image acquisition at short recovery times TI (3, 4).
In this work, we present a model-based image reconstruction for radially acquired data, providing one fully reconstructed image for every single acquired radial projection. While the images with longer TI provide signal time curves with high SNR, a saturation free AIF can be derived from the images with short TI.

Material and Methods:

Subsequent to a saturation recovery magnetization preparation, the signal intensity $S(x,y,t)$ in the voxel (x,y) can be described by a simple exponential model:

$$S(x, y, TI) = S_0(1 - e^{-TI/T1^*}) \quad (1)$$

with S_0 being the steady state magnetization and $T1^*$ the apparent relaxation time of the tissue in the voxel. Having performed the image acquisition with a radial trajectory, each acquired projection contains information about the image contrast at its acquisition time point TI.

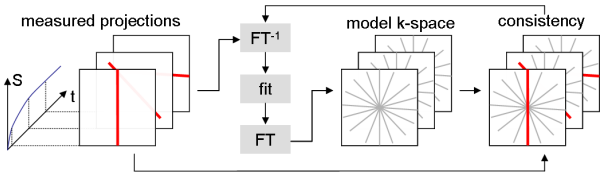

Fig. 1: *Iterative model based reconstruction algorithm (FT: Fourier transform, fit: pixelwise analytical linear regression)*

By utilizing the contrast information of all acquired projections and constraining the image reconstruction using the signal model (eqn. 1), a complete image can be reconstructed for each of these projections. For this purpose, each single radial projection is gridded onto a Cartesian k-space using self-calibrating grog (5). Subsequently, each k-space is Fourier transformed and passed on to the iterative model based image reconstruction algorithm (Fig. 1). During each iteration, model images are created based on a pixelwise analytical linear regression (fit). Before passing the model images to the next iteration, data consistency is assured by substituting the originally measured radial projections into the k-space of the corresponding model images.
Contrast enhanced in-vivo myocardial first-pass perfusion measurements were carried out on a clinical 1.5T whole-body scanner (Magnetom Avanto Siemens AG Healthcare Sector, Erlangen, Germany) equipped with a 32 channel cardiac array (Rapid Biomedical, Rimpar, Germany). Imaging was performed using a Saturation-Recovery SSFP sequence (FOV = 320 x 320 mm^2, TE = 1.28 ms, TI_{eff} = 105 ms, TR = 2.6 ms, T_{acq} = 190 ms, flip angle 50°) and a Golden Ratio radial k-space trajectory (6) with 64 projections and 128 readout points. The pass of the contrast agent (4ml, Gadovist, Bayer Schering Pharma, Berlin) was imaged by 40 measurements over 40 consecutive heartbeats.
The reconstruction algorithm was applied for 100 iterations. For each of the 40 measurements, 64 images were reconstructed, one for each sampled radial projection. For comparison, additional images were reconstructed from all 64 projections using grog. Arterial input functions were determined for several recovery times TI and normalized for comparison using the mean signal of the last 5 measurements.

Results:

The iterative model based reconstruction algorithm could be successfully applied to reconstruct one complete image for every sampled radial projection. Thus, for each RR interval, the signal evolution after the saturation recovery magnetization preparation could be completely resolved. Fig. 2, shows a comparison of images reconstructed for different recovery times TI. The images show the pass of the contrast agent through the right and left ventricle and the myocardium. In addition, reference images sustained by performing a grog reconstruction from all projections sampled during the signal recovery are depicted. The image quality of the reconstructed images is comparable to that attained with a conventional grog reconstruction. Normalized left-ventricular arterial input functions (AIF) derived from the reconstructed images for several TI are shown in Fig. 3. The saturation effect for higher TI is clearly visible. The AIF derived from the grog reconstruction shows almost exactly the same behavior as the AIF determined from the model reconstruction for the same effective TI.

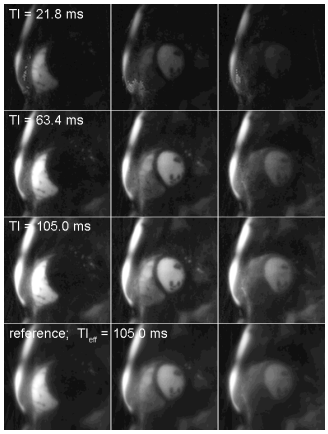

Fig. 2: *Comparison of images reconstructed for several recovery times TI. Shown is the pass of the contrast agent through the right* ***(left column)*** *and left* ***(middle column)*** *ventricle as well as the myocardium* ***(right column)****. The bottom row shows the corresponding images from the grog reconstruction.*

Discussion:

By reconstructing one image for each acquired radial projection, the proposed model based reconstruction algorithm offers the possibility to exactly resolve the relaxation process after the saturation recovery magnetization preparation. Consequently, signal intensity time curves can be determined for different recovery times TI allowing for a saturation free estimation of the AIF. While conventional techniques for myocardial blood flow quantification require the acquisition of two datasets, i.e. one for the AIF and one for the signal time curves, the proposed technique provides all information within one scan.

References:

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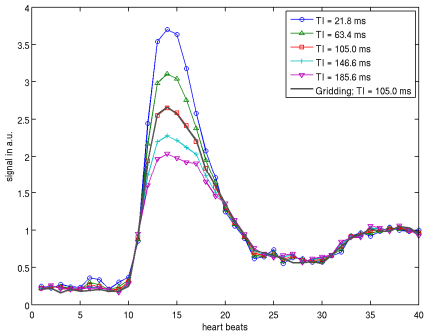

Fig. 3*: Normalized arterial input functions derived for different recovery times TI*