Viability Imaging with a T1-weighted Radial Acquisition using Interleaved Weighted Projections

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Introduction: Viability MR imaging with a radial acquisition method may provide higher spatial resolution images of myocardial infarct than is possible with Cartesian breath-hold acquisitions, through undersampling. It has recently been shown to be feasible, and allows for a sliding window reconstruction with a variable TI [1]. However, because each projection contains central k-space signal, radial imaging has the limitation that preparation pulses, like those used for the delayed enhancement technique, provide an angular contrast weighting, instead of the smooth weighting over ky-space obtained with Cartesian imaging. The standard solution is to keep the data acquisition window short. A recently presented method called KWIC [2] for radial fast spin echo imaging of the brain showed that applied weightings to interleaved projections sets improved the T2 contrast by only including central k-space data from a specific TE time. Here the method is adapted for radial Gd-enhanced delayed hyperenhancement imaging, as described below.

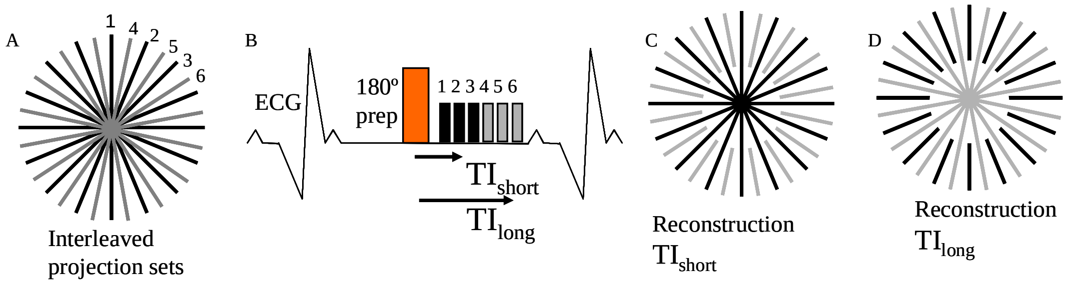

Figure 1: 2 interleaved projections sets were used (A) labelled 1-6, timed so that projections from 1st interleaf (1-3) were acquired earlier after the preparation pulse than those from the 2nd interleaf (4-6). Reconstruction was performed by including only central k-space from a single projection set (C, D).

Methods: Figure 1 shows the method for collecting and weighting k-space data. The projections were divided into two interleaved sets (grey and black spokes in Fig 1A). After the preparation pulse, N views are collected, here shown for N=6. Acquisition timing was such that in each data acquisition segment the first 3 views collected belong to the first interleaf (black spokes) and the next 3 belonged to the 2nd interleaf (grey spokes). Reconstruction was performed offline. The two interleaves were combined for reconstruction as shown in Fig. 1C and 1D, where a single interleaf, was used for central k-space data. Both interleaves were used for the outer k-space data. If the first set of projections were used for central k-space (reconstruction of Fig. 1C), then the effective TI after the 180º preparation pulse is defined in Fig. 1B as TI_{short}. Otherwise (for reconstruction of Fig. 1D) the effective TI was TI_{long}. The central region was weighted (using smooth Fermi filters) by a factor of two to provide density correction. Delayed enhancement imaging was performed on a Philips 1.5T Gyroscan ACS-NT (Philips Medical Systems, Best, NL). Radial acquisition parameters typically were: 180º preparation pulse, TI time: 440 ms (short), 520 ms (long), 32 cm FOV, 10 mm slice, 160 Nr, 144 Np, TR/TE/θ = 4.6ms/2.1ms/15º, Turbo factor = 36 views, BW = 440 Hz/pixel, gradient-echo readout, 2 RR intervals between preparation pulses, 1 NSA, full echoes. Imaging was performed 15 minutes after administration of 0.1 mmol/kg of gadolinium.

Figure 2: Radial image of infarction in a swine with spatial resolution of 1.4 x 1.4 x 7.5 mm^3, reconstructed without weighting.

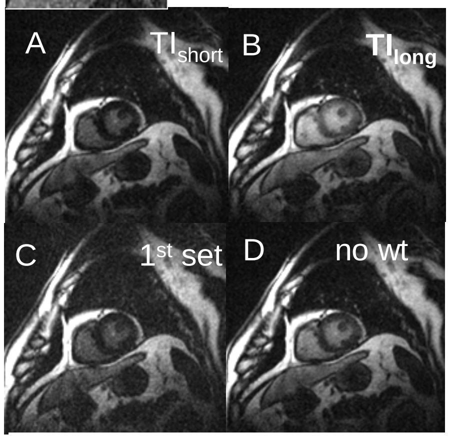

Figure 3: Results of viability imaging using the weighted k-space method to reconstruct an image with a short TI (A) or long TI (B), compared with reconstructing a single interleaf (C, interleaf 1) or an image with no weighting (D). The image in (A) has greater myocardial nulling than (B) or (D), and higher SNR than (C).

Results: Figure 2 shows radial viability imaging in a swine with an infarction, using the conventional acquisition order and no weighting. Figure 3 shows a delayed enhancement image in a patient (no infarct present) using the acquisition and weighting scheme of Fig. 1. Fig. 3a shows a short TI image, using the 1st interleaved set for central k-space data (reconstruction of Fig 1C), and Fig. 3B shows a long TI image. Note the increased signal in the blood pool and myocardium for Fig. 3B due to increased signal regrowth (vs. Fig. 3A). Figure 3C shows the reconstruction using only the first interleaf; SNR of these images is visually lower, as expected since less data were used in reconstruction. Figure 3D shows the results of adding both sets without weighting. The contrast is intermediate between 3A and 3B.

Conclusions: The use of interleaving combined with k-space weighting [2] improves the quality and effectiveness of an inversion pulse for viability imaging with the radial acquisition method. The method presented can be extended to enhance the capabilities of radial acquisition in combination with preparation pulses generally. Future work will include investigation of four interleaved projection sets [3] to smooth the weighting of k-space further, and use of bent radials for reducing artifacts when undersampling [4]. The important cardiac MR application of radial perfusion [5] will also be studied.

References: 1. Unal O, ISMRM 2003, 1604. 2. Song HK and Dougherty L. MRM 44:825 (2000). 3. Altbach, MI et al. ISMRM 2003, 1070. 4. Toropov Y et al, ISMRM 2001, 1809. 5. Pilla JJ, Doughtery L, ISMRM 2003 1659.