Dixon Imaging with Golden Angle Stack of Stars Acquisition

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Purpose

In this study, the combination of radial stack of stars k-space sampling with dual-echo readout Dixon water-fat separation is demonstrated. This is enabled by a radial phase correction, which is performed on-the-fly without requiring pre-scan calibrations relying on imaging data only. Two types of radial sampling schemes are considered: uniform angular sampling with alternating readout directions, which has optimal properties for the phase correction and optimal SNR, and golden angle sampling, which leads to an irregular quasi-isotropic angular sampling of k-space and high flexibility [1-3]. The phase correction method preserves phase information for Dixon methods, is robust to radial undersampling, stable over long scan durations, and works for golden angle acquisitions.

Methods

A 3D stack of stars acquisition was used, with Cartesian phase encoding in slice (FH) direction and radial sampling in-plane. A dual-echo mDIXON sequence was used with TR = 3.9 ms, TE_1 = 1.1 ms, TE_2 = 2.0 ms and 10° flip angle [4]. In vivo abdominal images were obtained on a Philips Ingenia 3T scanner with a 12 channel posterior and a 16 channel anterior coil from 7 healthy volunteers, with a FOV of 450 × 450 × 225 mm^3 and 2 × 2 × 2.5 mm^3 voxel size. Two radial sampling schemes were used (c.f. *Figure 1*): First, uniform sampling, where the angle between adjacent readouts is constant, while their polarity is alternating; second, golden angle sampling, where the angle increment between two successive readouts is given by 111.25°. Assuming, that the timing delays are independent of the gradient polarity, the induced phase errors are corrected during reconstruction using information from (nearly) anti-parallel readouts as described in [4, 5]. The phase correction equalized zeroth and first order terms, while preserving the chemical shift-induced phase differences for subsequent Dixon water-fat separation. 448 profiles per image were acquired from free breathing subjects, and 78 profiles per image were acquired during breath holds. Images from individual coils were separately gridded and combined via an optimal Roemer [6] reconstruction taking the receive coil sensitivities into account. Although this is not the optimal image reconstruction for subsampled data, it reduces the propagation of streaking artifacts due to inherent coil sensitivity.

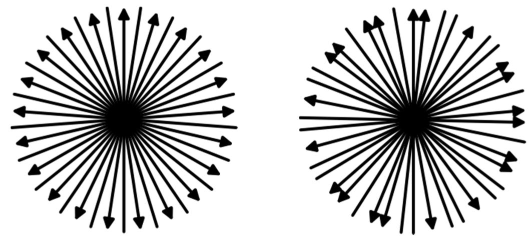

Figure 1 *Radial readout trajectories with 21 profiles using uniform, bipolar (left) and golden angle view ordering (right).*

Result

Transversal slices of the reconstructed water and fat images are displayed in *Figure 2* and *Figure 3*. Water and fat are clearly separated without any Dixon artefacts. The images with high profile counts shown in *Figure 2* were acquired from a freely breathing volunteer over an 83 second time frame. Due to the oversampling in the k-space center, motion artefacts are greatly reduced, albeit blurring is observable in fine structures and some residual streaking mostly in the arms. The images with significantly lower radial sampling density in *Figure 3* were acquired during a 16 seconds breath hold of the volunteer and thus show sharper edges due to the absence of motion while exhibiting stronger streaking artefacts due to the azimuthal undersampling.

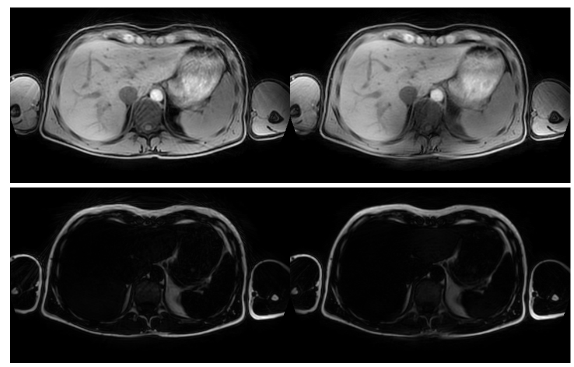

Figure 2 *Water (top) and fat (bottom) images acquired with uniform (left) and golden angle (right) profile ordering. 448 profiles acquired in 83 seconds, free breathing.*

Discussion

The results show that dual-echo Dixon imaging with uniform and golden angle radial acquisitions yield images with good water-fat separation. Prerequisite for this is a reliable phase correction of the radial profiles. The method employed here uses the information directly from the acquired echoes and hence does not require any pre-scan calibration. The phase correction scheme is robust to strong radial undersampling as well as to prolonged acquisition times. The former is of interest when using the golden angle acquisition order for retrospective motion correction techniques such as respiratory or cardiac motion state binning or sliding window reconstruction. The latter shows the ability of this technique to compensate for temporal variations of the gradient system characteristics during lengthy scans due to e.g. temperature increases in the gradient coil.

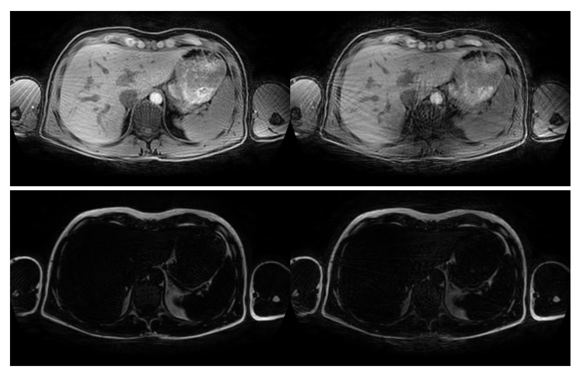

Figure 3 *Water (top) and fat (bottom) images acquired with uniform (left) and golden angle (right) profile ordering. 78 profiles acquired in 16 seconds during breath hold.*

References

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