Image Based Radial Dixon With Asymmetric Time Shifted Echoes

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Introduction: Fat-water separation is critical in many fast spin echo (FSE) torso acquisitions due to the high intensity of fat signals. However, fat saturation is often inconsistent over a large field of view, and Dixon FSE methods require multiple acquisitions that extend acquisition time. Radial acquisition (projection reconstruction) presents the potential for quick Dixon fat-water separation using a single acquisition since all views traverse the center of k-space. However, initial work (1) suffered from loss of time efficiency by shifting full symmetric readouts for Dixon imaging. In addition, all Dixon processing was performed in k-space, since the in- and opposed-phase data were radially undersampled hence was not suitable for more robust image-based algorithms since. The KWIC (k-space weighted image contrast) technique (2) produces multiple images from a single set of acquired data but avoids radial undersampling artifacts by a progressive k-space filling scheme. While the outer region of k-space is shared for all the images, the inner region for a given subset consists only of selected views, which determine the contrast of the image. In this work, we investigated the feasibility of applying this concept to data acquired with a novel radial Dixon fast recovery FSE (FR-FSE) pulse sequence (driven equilibrium Fourier transform imaging) (3). Our aim is to develop a multislice Dixon FR-FSE imaging technique with image based processing and uncompromised time efficiency.

Methods: All imaging experiments were performed on a Signa EXCITE 3T scanner (General Electric Healthcare, Waukesha, WI) with Twinspeed gradients and G3 software, using product birdcage head and extremity coils. Axial slices through an oil/water phantom and sagittal slices through the knees of healthy volunteers were acquired with a radial FR-FSE sequence, prescribed with the following parameters: TR = 650 ms, ETL = 8, readout bandwidth = +/- 31.25 kHz, echo spacing = 13.152 ms, FOV = 40 cm, slices = 4, slice thickness = 5 mm, 256 views, 256 pts/view, refocusing pulse flip angle = 160°, total acquisition time = 27 sec. View ordering followed a "bit-reversed" order (4). Every other radial view was an asymmetric echo shifted forward by 1.12 ms (figures 1, 2), and was acquired by fixing the ADC readout window but adjusting the pre-winding and rewinding gradients (figure 2). KWIC reconstruction was performed with MATLAB software (Mathworks, Natick, MA) running on a 1.2 Ghz Pentium III personal computer. In- and opposed-phase sets of k-space data were formed by selective regridding and weighting of a single set of acquired raw data. The data in the central region of each regridded k-space was restricted to data from views acquired with a selected echo shift (0 or 1.12 ms) to produce expected phase properties of that echo shift. A phase correction algorithm without direct phase unwrapping was then applied before separating the lipid and water images (5).

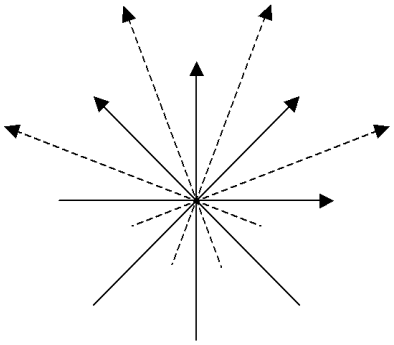

Figure 1. Radial Dixon acquisition in k-space. Dotted lines represent time shifted asymmetric echoes. Alternate views are dropped in central region while maintaining Nyquist criterion.

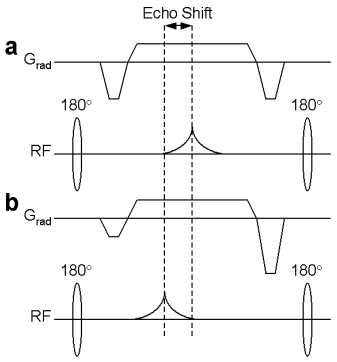

Figure 2. Period between 180° pulses in Dixon radial FSE. (a) conventional symmetric spin echo (b) shifted asymmetric echo.

Results: Figures 3a-c show the combined, water, and lipid images of the oil/water phantom. Figures 3d-f show the combined, water, and lipid images of the volunteer knee. Images exhibited very little radial interference artifacts, though resolution loss was observed in some separated images.

Discussion: The KWIC technique relies on the fact that the central region of k-space is oversampled in a radial acquisition. If data masking is limited to this region, Nyquist criterion is satisfied while preventing the interference of in- and opposed-phase data that would otherwise cause streaking artifacts in these images.

Conclusion: Symmetric and asymmetric data from a time-optimized radial Dixon FSE can perform robust fat/water separation with reduced radial interference artifacts when processed with the KWIC technique.

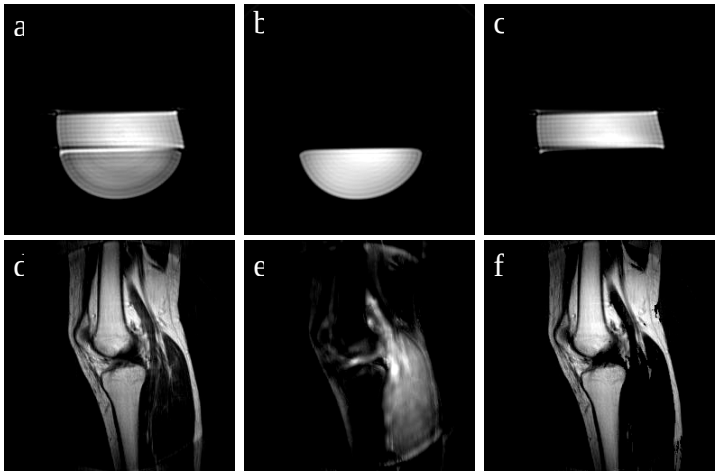

Figure 3. Combined (a,d), water (b,e) and lipid (c,f) images of an oil/water phantom (a-c) and volunteer knee (d-f).

References: 1) Flask et al, MRM 50:1095-1099(2003), 2) Song and Dougherty, MRM 44:825-832 (2000), 3) Hargreaves et al, MRM 42:695-703 (1999), 4) Theilmann et al, MRM 51:768-774 (2004). (5) Ma, MRM 52:415-9 (2004)