A single scan two-point Dixon technique for projection reconstruction using Bunched Phase Encoding

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Introduction: Projection reconstruction (PR) has re-emerged in MRI since they have advantages over rectilinear acquisition methods, e.g. reduced motion artifacts compared with rectilinear acquisitions [1]. An fat signal suppression method using PR acquisition with alternate TE has been proposed [2]. In this method, odd and even projections have different TE's and their TE difference is set to the time during which fat spins rotate by 180° with respect to water spins. Since fat signals cancel at the center of k-space, the method provides fat-suppressed images. However, fat signal cancellation may be incomplete for regions where applied magnetic field inhomogeneity cannot be ignored. Furthermore, data inconsistency between even and odd projections often gives rise to aliasing artifacts (a.k.a. streaking artifacts in PR) in the reconstructed images. Two-point Dixon (2PD) [3] and Spiral two-point Dixon (Spiral 2PD) techniques [4] are methods of water-fat decomposition using two sets of images with different TE's for rectilinear and spiral acquisitions, respectively. These techniques achieve unequivocal water-fat separation even in the presence of magnetic field inhomogeneity. Spiral 2PD technique also corrects for blurring artifacts due to off-resonance effects. If two separate images are reconstructed from each of odd and even projections in PR with alternate TE, 2PD techniques can be used for water-fat separation. However, streaking artifacts are unavoidable because each image is reconstructed from half of the acquired projections. In this study, we show that this drawback can be overcome by using PR-Bunched Phase Encoding (PR-BPE) that has recently been proposed [5]. PR-BPE is an extension of BPE [6, 7] to PR acquisitions. In PR-BPE, a zigzag trajectory is used for each projection and the total number of projections can be reduced. The newly proposed method is referred to as 'PR-BPE-2PD technique'. We also compare quality of the images reconstructed using different PR acquisitions and reconstruction methods.

Methods: Figure 1 shows a schema of center-out PR k-space trajectories used in our experiments. Each projection forms a zigzag trajectory and TE is changed for alternate projections. The TE of solid and dashed projections are equal to $n\tau$ and $(n+1)\tau$, respectively, where n is a positive integer. τ is defined as $1/(2f_{fat})$, where f_{fat} is a chemical shift off-resonance frequency. Figure 2 is a flow chart of the PR-BPE-2PD technique. Data with TE1 and those with TE2 are first separated. An image is reconstructed independently from each data set. Conjugate gradient - iterative next neighbor gridding (CG-INNG) method with a single coil [6] is used in this reconstruction step. 2PD algorithm is then applied to the reconstructed images. As is also the case with spiral imaging, center-out PR acquisitions cause blurring artifacts due to off-resonance effects because phase error accumulation is isotropic with respect to the k-space origin for both spiral and center-out PR trajectories. Therefore, when blurring artifacts need to be corrected, the algorithm that is identical to Spiral2PD algorithm [4] is used, i.e. several predetermined off-resonance frequecies are tested to decompose and deblur water and fat signals and the correct frequency is determined at each location in the image by checking the phase relationship between water and fat signals. As a result, water and fat images can be created with blurring artifacts adequately corrected for the entire image domain.

MR experiments were performed to test the PR-BPE-2PD technique using a 1.5 Tesla Siemens Sonata Scanner. Axial abdominal images were acquired from an asymptomatic volunteer. The experiments were performed under an institutional-review-board-approved protocol for volunteer scanning. We designed both PR-BPE and regular PR (no zigzag). Each PR consists of 402 projections with the readout 5.12ms in duration. In PR-BPE, 128 oscillations were incorporated into each projection. In both PR, the sequence type was FISP and TE1/TE2/TR/FA=2.3/4.6/10.0ms/30°. Data were acquired using a four-element phased array surface coils. We tested two image reconstruction methods: conventional gridding [8] and CG-INNG method. The target image size was 256 x 256. Spiral2PD algorithm was used for water-fat separation. In CG-INNG method, scaling factor was set to 16 and 20 iterations were performed. An image was reconstructed from the data acquired from each receiver coil. The final image was created using the sum-of-squares method [9]. Another image was reconstructed by directly performing gridding on the whole acquired data [2] for comparison.

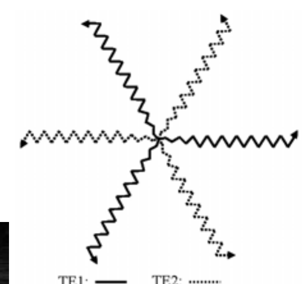

Fig.1. Center-out PR-BPE trajectories

Results: Figure 3 shows the reconstructed images ((a): Image from regular PR with conventional gridding using the whole data; (b): Water image from regular PR with conventional gridding; (c): Water image from PR-BPE with conventional gridding; and (d): Water image from PR-BPE with CG-INNG). Uniform fat suppression is achieved in (b)-(d) while fat signals remain for large portions of subcutaneous tissues in (a). Streaking artifacts are observed in all the images reconstructed using conventional gridding (a)-(c) (indicated by arrows). The streaking artifacts are considerably reduced in (d) from those in (a)-(c).

Discussion and Conclusions: In (a), although the whole acquired data are used for reconstruction, streaking artifacts are still observed for wide regions of the image. It is presumed that the artifacts result from inconsistency between data with TE1 and those with TE2. As seen in (b) and (c), when conventional gridding is used, the reconstructed water images exhibit streaking artifacts for both regular PR and PR-BPE acquisitions. The artifacts appear because each image before signal decomposition is reconstructed from only 50% of the acquired k-space data. When CG-INNG method is used with PR-BPE, no apparent streaking artifacts are seen, as shown in (d). Note that streaking artifacts still remain in a water image reconstructed from regular PR using CG-INNG (not shown). Also, there is some resolution loss in this image. The newly proposed PR-BPE-2PD technique offers a quite efficient fat suppression method in a scan time equivalent to single acquisition without compromising image quality.

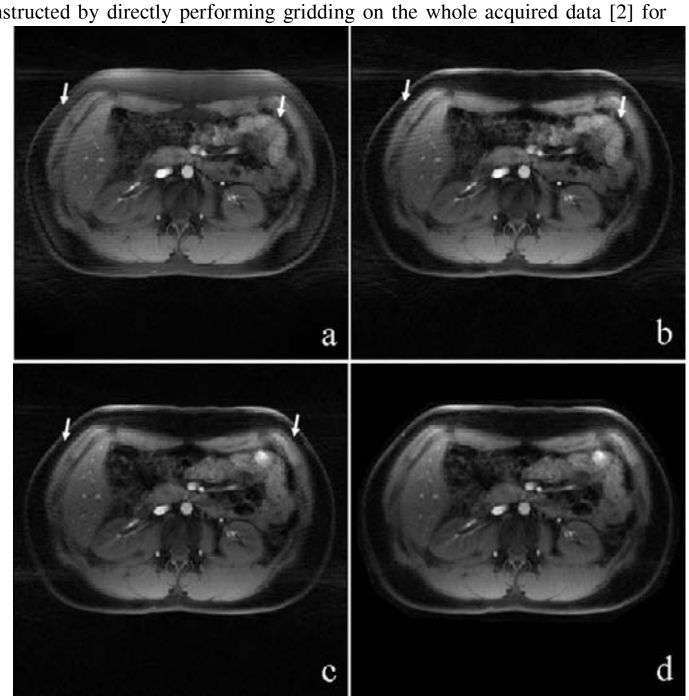

Fig.3. Reconstructed images

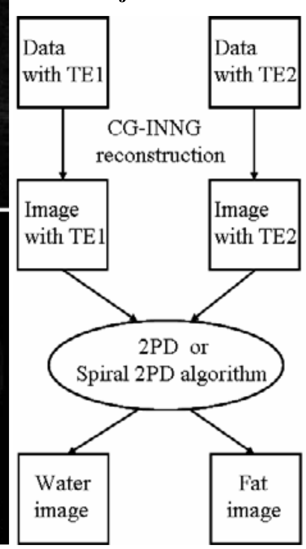

Fig.2. A flow chart of PR-BPE-2PD technique

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