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

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Introduction: The two-point Dixon (2PD) technique is a method for water-fat decomposition using two sets of images with different TEs [1]. This technique is capable of achieving unambiguous water-fat separation even in the presence of magnetic field inhomogeneities. However, the need to acquire two sets of images prolongs MR scan time, giving rise to the primary drawback of the original 2PD technique: the extended scan time increases patients' burden and may increase motion artifacts and motion-dependent misregistration between the acquired data sets. Ideally, the entire acquisition time of the 2PD technique would be reduced. Bunched Phase Encoding (BPE) has recently been proposed as a new fast data acquisition method in MRI [2, 3]. In BPE, data are acquired along zigzag k-space trajectories using rapidly oscillating gradients along the phase encoding (PE) direction during data acquisition in which the sampling frequency is higher than that of a conventional acquisition. The BPE acquisition scheme is comparable to acquiring multiple PE lines in a single readout. Therefore, the total number of TR cycles and hence the scan time can be reduced; it is analogous to parallel imaging in K-space. In this study, we show that the total data acquisition time of the 2PD technique can be reduced to that of a single acquisition by capitalizing on the BPE technique. To the best of our knowledge, this is the first demonstration of the application of the BPE to the 2PD technique in Cartesian sampling.

Methods: Suppose that the standard rectilinear acquisition method consists of *N* PE lines with *N* samples acquired during each readout. In the newly proposed BPE-2PD technique, the sequence consists of *N* TR cycles and TE is alternately changed for each TR. Figure 1 shows a flow chart of the BPE-2PD technique. In the leftmost schema of Fig.1, solid and dashed lines represent oscillating trajectories used to acquire k-space data. It is assumed that TEs of k-space data at solid and dashed lines are equal to $n\tau$ (=TE1) and $(n+1)\tau$ (=TE2), respectively, where n is a positive integer. τ is the time during which fat spins precess by 180° with respect to water spins, i.e. $\tau = 1/(2f_{fat})$, where f_{fat} is a chemical shift off-resonance frequency. As shown in Fig.1, a separation between k-space trajectories with the same TE is $2\Delta k_y$, where Δk_y is defined as $1/\text{FOV}_y$. FOV_y is the prescribed field-of-view along the PE direction. Therefore, each k-space data set with a constant TE can be acquired for $N/2$ TR cycles. The BPE matrix inversion method [2] enables us to reconstruct an image from each data set without aliasing artifacts or loss of resolution. Then, the images with TE1 and TE2 are processed using the original 2PD technique [1] to achieve separate water and fat images.

MR experiments were performed to test the proposed BPE-2PD method using a 1.5 Tesla Siemens Sonata Scanner. Axial abdominal images were acquired from an asymptomatic volunteer under breath-hold. The experiments were performed under an institutional-review-board-approved protocol for volunteer scanning. A series of triangular gradients with the maximum amplitudes ±3.7mT/m was used to produce zigzag k-space trajectories. 128 oscillations were performed during each readout. The readout is 10.24 ms in duration and 1024 samples were acquired. The sequence was a FISP sequence [4] with TE1/TE2/TR/FA=9.2/11.5/20.0ms/30°. The sequence consisted of 256 TR cycles, i.e., 128 TR cycles were used to acquire each data set with the same TE. The total acquisition time was 5.1sec. Data were acquired using a four-element phased array surface coils. The reconstructed image matrix was 256 x 256. An image was reconstructed independently from the data acquired from each receiver channel. A magnetic field map was derived from images acquired from all four receiver channels. For the data from each channel, water-fat decomposition was performed based on this field map. The decomposed images were combined using the sum-of-squares method [5]. A simple reconstruction using a conventional gridding [6] from the whole acquired data was also performed for comparison.

Results: Figure 2 shows the reconstructed images ((a): Image from the whole acquired data; (b): Water image using the BPE-2PD technique; (c): Fat image using the BPE-2PD technique.). In (a), a water signal-dominant image appears at the center while fat signal-dominant aliasing artifacts can also be seen at the peripheries. In each image of (b) and (c), no apparent artifacts are observed and unequivocal water and fat signal separation is achieved for the entire image domain.

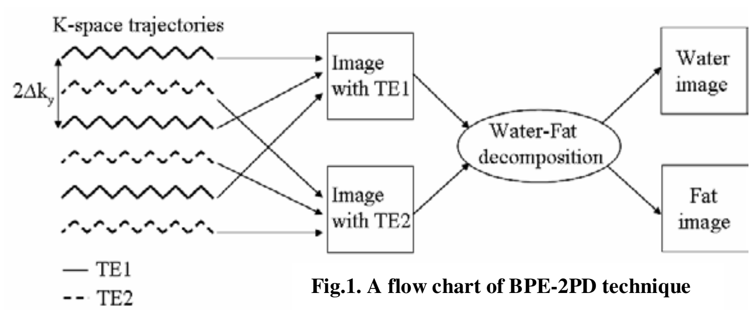

Fig.1. A flow chart of BPE-2PD technique

Discussion and Conclusions: Since an alternating TE acquisition scheme was used in our experiments, the phase of fat signals alternated from one TR to the next. Therefore, as shown in Fig.2 (a), fat signals were shifted from the water signals. Since the k-space trajectories used in this experiment were zigzag trajectories, fat signals were shifted along readout direction as well as the PE direction. In a previous study with alternate TE acquisition [7], shifted fat signals were eliminated using a parallel imaging method [8] and only water signals were extracted. These earlier methods had a number of disadvantages: 1) the water and fat signal components are superimposed and difficult to decompose unless additional information is available; 2) the shifted signals are not purely fat or water components if magnetic field inhomogeneity is non-negligible; 3) when a relatively large FOV is prescribed, it is sometimes difficult to achieve sufficiently homogeneous magnetic field for the entire FOV even if shimming is performed, and 4) when breath-hold is required for patients during scanning, extended scan time often increases the patients' burden. However, the newly proposed BPE-2PD technique does not use parallel imaging approaches, thereby eliminating the need for for pre-scans to obtain sensitivity maps. As observed in Fig.2 (b) and (c), water - fat decomposition are successfully done for the entire image domain. The BPE-2PD technique maintains advantages of the original 2PD technique [1] while the whole scan time is reduced to 50% of that of the 2PD technique. The BPE-2PD technique is a new, fast water-fat separation method that is quite useful in practice.

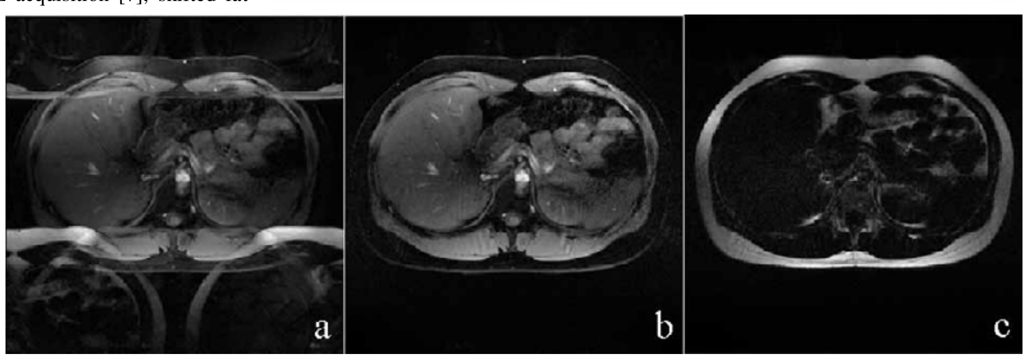

Fig.2. Reconstructed images

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References: [1] Coombs BD, et al. MRM 1997;38:884-9. [2] Moriguchi H, et al. Proc RSNA 2004. p451. [3] Moriguchi H, et al. Proc ISMRM 2005. p287. [4] Haacke EM, et al. Radiology 1990;175:545-52. [5] Roemer PB, et al. MRM 1990;16:192-225. [6] Jackson JI, et al. IEEE TMI 1991;10:473-8. [7] Flask CA, et al. Proc ISMRM 2004. p269. [8] Kellman P, et al. MRM 2001;46:335-43.