Spiral Dixon Techniques Using Sensitivity Encoding

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Introduction

Spiral Dixon techniques have recently been proposed as methods for water-fat decomposition with effective blurring artifact correction [1]. In these techniques, spatial-spectral RF pulses are not required in data acquisition and unambiguous water-fat separation can be achieved even in the presence of B_0 inhomogeneities. Although multiple data sets are acquired in these techniques, this is not viewed as a significant limitation compared with conventional spiral data acquisitions since conventional spiral methods often require two data sets with different TEs to create a frequency field map for off-resonance correction. However, it would be desirable to reduce Spiral Dixon acquisition time since shorter acquisition times reduce motion artifacts as well as motion-dependent misregistration among the data sets. In this study, we show that sensitivity encoding (SENSE) [2,3] can be used advantageously in the Spiral Dixon techniques to reduce the data acquisition time. The newly proposed techniques are referred to as 'SENSE-Spiral Dixon techniques'. To the best of our knowledge, this is the first demonstration of application of sensitivity encoding to Spiral Dixon techniques. The recently proposed POCSENSINNG algorithm [4] is used for image reconstruction from sensitivity encoded k-space data acquired with spiral trajectories.

Methods

In Spiral Dixon techniques, three or two data sets are acquired with different TEs [1]. These methods are referred to as the spiral three-point Dixon (Spiral 3PD) and spiral two-point Dixon (Spiral 2PD) techniques, respectively. To reduce the scan time in these techniques, each set of data are acquired using multiple receiver channels with a fewer spiral interleaves than that required for the prescribed field-of-view (FOV). An image is reconstructed from each k-space data using the POCSENSINNG algorithm [4]. Images with different TE's are reconstructed and processed using the Spiral Dixon algorithms to achieve water-fat decomposition and de-blurring [1]. In the method described above, it is assumed that sensitivity profiles for each receiver channels are acquired separately. In general, SENSE requires a prescan (or calibration) to obtain sensitivity profiles of the receiver coils. This requirement often increases the total scan time. To avoid a prescan, one of the data sets may be acquired with full k-space data and the sensitivity profiles are created from the image reconstructed from the full data set.

The newly proposed SENSE-Spiral Dixon techniques were applied to in-vivo MR data. Data acquisitions were performed with a 1.5-Tesla Siemens Sonata scanner (Siemens Medical Solutions, Erlangen, Germany). Abdominal images were acquired from an asymptomatic volunteer using a four-element phased array torso/body surface coil. Three sets of axial abdominal images were acquired using spiral trajectories with TEs 2.2/4.4/6.6ms. Twelve spiral interleaves were designed for an FOV of 390 x 390mm. The first data set (TE 2.2ms) was acquired using all twelve spiral interleaves. The other two data sets (TEs 4.4/6.6ms) were acquired using six of the twelve interleaves (i.e., reduction factor = 2). The slice thickness was 10mm, the spiral readout time was 16.0ms. TR was 30.0ms. The flip angle was 16°.

First, sensitivity profiles of the receiver coils were created from images reconstructed from the first data set. Images were reconstructed from the second and third data sets using the POCSENSINNG algorithm and the computed sensitivity maps. 20 iterations were performed to reconstruct each image in the POCSENSINNG algorithm with scaling factor 2. The Spiral 3PD algorithm was applied to all three reconstructed images to perform water-fat decomposition with blurring artifact correction. The Spiral 2PD algorithm was also tested using the images reconstructed from the first and second data sets (TEs 2.2/4.4ms).

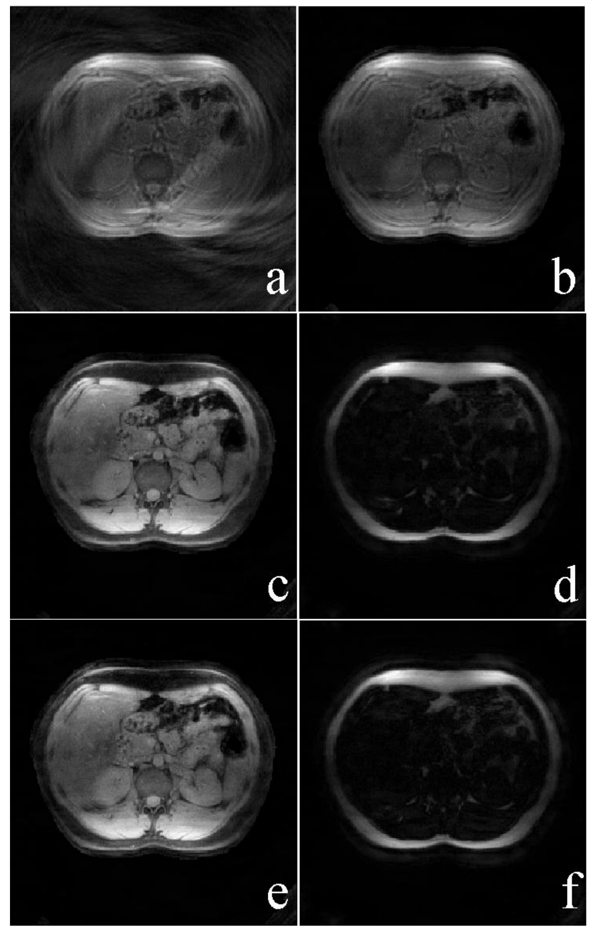

Figure 1. Reconstructed abdominal images.
(a) Original image reconstructed from 50% k-space data of the Nyquist limit using sum-of-squares method;
(b) Image reconstructed from the same data as (a) using POCSENSINNG algorithm;
(c) Water and **(d)** fat images reconstructed using SENSE-Spiral 3PD technique;
(e) Water and **(f)** fat images reconstructed using SENSE-Spiral 2PD technique.

Results

Figure 1 shows the reconstructed images. (a) is the original image reconstructed from the data with TE 4.4ms using a sum-of-squares algorithm. (b) is the image reconstructed from the data with TE 4.4ms using the POCSENSINNG algorithm. (c) and (d) are the water and fat images reconstructed using SENSE-Spiral 3PD techniques, respectively. (e) and (f) are the water and fat images reconstructed using SENSE-Spiral 2PD techniques, respectively. Aliasing artifacts observed in (a) are effectively reduced in (b) as expected from use of the POCSENSINNG algorithm. As seen (c)-(f), unambiguous water-fat decomposition and blurring artifact correction can be achieved in SENSE-Spiral Dixon techniques.

Discussion and Conclusions

Application of SENSE to the Dixon techniques in rectilinear acquisition has recently been proposed to speed up the data acquisitions [5]. Here, we demonstrate SENSE-Spiral Dixon techniques provide opportunity for reduced scan time for the Spiral Dixon techniques [1]. We have demonstrated that unambiguous water-fat separation and effective de-blurring can be performed in the SENSE-Spiral Dixon techniques. In spiral imaging, off-resonance effects cause blurring artifacts. Moreover, aliasing artifacts due to undersampling are not localized in the image domain. These effects introduce additional complexity when SENSE is utilized for the Spiral Dixon techniques. However, the POCSENSINNG algorithm [4] effectively reduces the spiral aliasing artifacts and maintains the water-fat phase relationship among the data sets with different TEs, thereby enabling water-fat decomposition, de-blurring and reduced acquisition time using the Spiral Dixon algorithms. The Spiral Dixon techniques avoid the need for spatial spectral pulses and therefore provide a way for further reductions of the acquisition time of conventional spiral imaging. The newly proposed SENSE-Spiral Dixon techniques further reduce the acquisition time and achieve unequivocal water-fat decomposition and effective de-blurring. The SENSE-Spiral Dixon techniques have a significant potential for real-time spiral MRI.

Acknowledgements NIH/NCC Grants R01 CA81431 and R33 CA88144, Siemens Medical Solutions.

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