Abdominal Three Point Dixon Imaging with Self Calibrating Parallel MRI

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Introduction: The three point Dixon technique (1, 2) can provide excellent separation of fat and water signals. This has a variety of potential applications, such as identification of fatty deposits in the liver. However, application of the technique to abdominal imaging has been severely limited by the requirement that three images, each with a different fat-water phase shift, must be collected, thus tripling acquisition time relative to an equivalent non-Dixon sequence. This increase in acquisition time, coupled with the necessity to acquire data within a single breath-hold (~20s), severely restricts the spatial resolution and/or anatomic coverage achievable with this method.

One advantage of Dixon imaging is that the separated images have SNR nearly equivalent to an acquisition with three averages (2). This makes Dixon imaging an ideal candidate for acceleration with parallel MRI, since the additional SNR of the Dixon technique can offset the SNR losses inherent in parallel MRI reconstruction.

All parallel MRI reconstructions require knowledge spatial sensitivity information for the coil array. The most common solution to the problem of coil sensitivity calibration has been to measure sensitivities directly using one or more fully gradient encoded calibration images. For abdominal imaging in particular, this introduces a possible source of error, as it is difficult to ensure that the patient and coil will be in exactly the same positions during both the calibration scans and the accelerated data acquisitions. Previous work on combining parallel imaging and the Dixon reconstruction has been done outside the abdomen, thus avoiding this calibration issue (3).

We propose to avoid the sensitivity calibration problem by accelerating two of the three Dixon images while acquiring the third with full gradient encoding. We will extract the necessary calibration information from fully encoded image. This guarantees correct measurement of the coil sensitivities, since the data to be reconstructed and the sensitivity data will be acquired simultaneously.

Methods: We obtained images from two healthy adult volunteers. The study was approved by the site Institutional Review Board and written consent was obtained from all volunteers.We performed all scans on a GE Signa 1.5T TwinSpeed MR imaging system (GE Medical Systems, Milwaukee, WI, USA) using a four element body array.

We acquired three point Dixon Fast Spin Echo (FSE) images (TR 1500 ms, TE 88.6,90.1 and 91.6 ms, BW ±19.23 kHz, ETL 16, 6 mm thick slice, 6mm gap, 40 cm FOV, 256×128 matrix) from five coronal slices through the liver. Two data sets were acquired from each volunteer. In the first set, all three images were acquired with full gradient encoding (no skipped phase encodes) in a 36 second breath-hold. In the second set, only one of the images was acquired with full gradient encoding. Every second phase encode line of the other two images of the Dixon acquisition were skipped, yeilding twofold accelerated data images. This resulted in an acceleration factor of 1.5 for the complete three image data acquisition, resulting in a more reasonable 24 second breath-hold.

The parallel MRI reconstructions were performed using a hybrid generalized encoding matrix (GEM) reconstruction (4). The coil sensitivity data necessary for GEM reconstruction of all three echoes were derived from the data for the second fully gradient encoded Dixon echo. Following GEM reconstruction, the resulting complex images were processed into separate water and fat images using an iterative least-squares water-fat decomposition method (2).

Results: Figure 1 shows examples of fully gradient encoded and accelerated three point Dixon FSE images. Fig. 1 A-C shows the fat only, water only, and the combined fat+water images respectively for the non-accelerated acquisition. Fig.1 D-F shows the corresponding accelerated images. The accelerated images have minimal artifact, good qualitative SNR and have image quality comparable to the images produced from fully sampled data sets.

Discussion: We have demonstrated the feasibility of combining self-calibrated parallel imaging with Dixon water-fat separation. By using self calibrated parallel imaging we have been able to accelerate Dixon imaging in the abdomen without encountering artifacts in the parallel MRI reconstruction from misregistration of the calibration and imaging data. Dixon water-fat separation is an SNR efficient technique, so SNR losses from the parallel reconstruction are mitigated by the gains from the extra scan time of the Dixon acquisition.. This makes the two methods very complementary and allows the final accelerated Dixon images to be of high quality. Further work is needed to clarify how SNR in the water and fat images is affected by processing the data through the parallel imaging-Dixon reconstruction combination.

A natural extension of this work will be to implement variable k-space sampling, as described in (5), for the "calibration" echo so that all three images can be accelerated while still preserving the self-calibrating nature of the data. This will make it possible to achieve acceleration factors of three or more. If a factor of three acceleration could be achieved it would be possible to produce images with SNR very similar to an equivalent non-accelerated non-Dixon image, but with all the advantages of near perfect fat-water separation.

Conclusion: We have demonstrated the feasibility of combining parallel imaging with "Dixon" water-fat separation for abdominal FSE imaging applications. Parallel imaging reduces the long minimum acquisition time needed for water-fat separation, while the high SNR efficiency of the Dixon reconstruction offsets losses in SNR from the acceleration in parallel imaging.

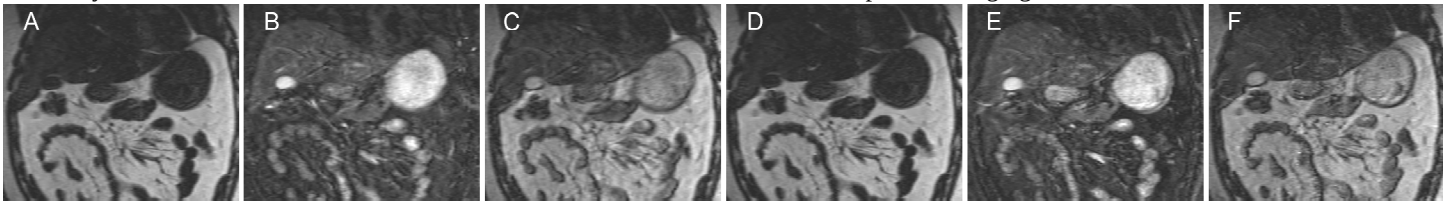

Figure 1

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