Inherent Correction of Rigid-Body Motion in Fast Spin-Echo Imaging

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TARGET AUDIENCE:
The aim of this work will benefit clinicians whose examinations require high-quality fast spin-echo (FSE) images free of rigid-body motion corruption.

PURPOSE:
FSE images are routinely acquired in clinical settings due to their range of available contrast and fast acquisition times [1]. However, despite the speed of FSE acquisitions, the presence of rigid-body patient motion during acquisition can cause each excitation to correspond to different patient positions, resulting in motion-corrupted images when using a standard reconstruction approach. Alternatively, if the level of rigid-body motion can be estimated in some manner, then these motion-corrupted images can be corrected using an improved reconstruction method. Here we present a novel method to accurately estimate and correct rigid-body motion corruption in FSE images inherently from the data itself, thus producing high-quality images appropriate for clinical use.

METHODS:
Sagittal 4-shot FSE images were acquired on a 3T system (GE HD, Waukesha, WI) with an eight-channel head coil (Echo train length = 64, Matrix size = 256x256, FOV = 25.6 cm, Slice Thickness = 5 mm, TR = 5000 ms, TE = 87 ms) at two different head positions. Rigid-body motion corruption was then simulated by combining data from both head positions; specifically, two different excitations were taken from each head position and combined into a single dataset. This corrupted dataset was used to evaluate our correction technique, which consists of the following steps. First, an initial SENSE reconstruction [2] is performed on each excitation of the data using smoothed estimates of the coil sensitivity profiles, resulting in four SENSE-produced images. Next, a 2D affine registration using FSL-FLIRT [3] is performed on the SENSE-produced images to give estimates of the rotation angles and displacements describing the rigid-body motion between excitations. Finally, the rigid-body motion parameters obtained from registration are used to build a multiplexed SENSE-based reconstruction matrix, in which the coil sensitivity profiles and data from all excitations are used to calculate a single image free of motion corruption. Two other reconstruction methods were used for comparison: 1) a direct FFT on the corrupted dataset (i.e. no motion correction), and 2) the registered original SENSE images combined. All processing was performed in Matlab (The MathWorks, Natick MA) on a Linux machine (2.30 GHz CPU, 16 GB RAM). Ghost-to-noise ratios (GNR) and signal-to-noise ratios (SNR) were calculated for each reconstruction method to assess their performance.

RESULTS:
Total computation time was approximately 30 seconds. Figure 1 shows the FSE images obtained with direct FFT (1a), registered SENSE images (1b), and our multiplexed reconstruction (1c). GNRs for the images (left to right) were: 16.9, 4.2, and 2.6. SNRs were: 62.6, 14.7, and 38.8.

DISCUSSION:
The image reconstructed from a direct FFT of the data contains both blurring and ghosting artifacts due to motion corruption. A reduction in blurring can be achieved by using the registered SENSE images, as seen in Fig. 1b. However, due to noise and inaccuracies in the estimated coil sensitivity profiles, the SENSE images are noisy and not fully unwrapped, as demonstrated by the residual aliasing patterns in the background. On the other hand, by using the registered SENSE images to obtain the rigid-body motion parameters (angles/displacements) and then applying them in a multiplexed reconstruction using information from all excitations, an image with significantly reduced blurring and ghosting artifacts as well as improved SNR can be produced (Fig. 1c). The increased SNR and lack of aliasing patterns in our technique are due to an improved conditioning of the multiplexed reconstruction as compared to SENSE. Consequently, the technique is more immune to reconstruction errors caused by inaccuracies in the estimated coil sensitivity profiles. While the computation time of the technique is far greater than that of a direct FFT, it is not prohibitively long, and is a favorable tradeoff for the considerable improvement in image quality. Furthermore, the technique can be applied to FSE acquired with any number of excitations, and thereby imposes no constraints on data acquisition.

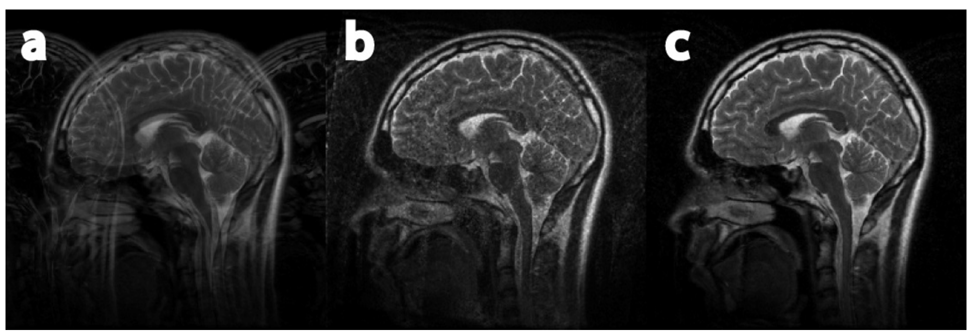

Figure 1: Motion-corrupted FSE data reconstructed with *(a)* direct FFT, *(b)* registered SENSE images, *(c)* the described multiplexed reconstruction technique.

CONCLUSION:
The reconstruction technique presented here can effectively correct errors due to rigid-body motion in FSE images. As a result, anatomy of clinical importance which may have otherwise been obscured can be clearly seen. The technique would therefore be valuable in a wide variety of clinical FSE applications in which images free of motion corruption are required.

REFERENCES:
[1] Liang ZP, Lauterbur C. Principles of Magnetic Resonance Imaging, (1999), [2] Pruessmann KP, et al. Magn Reson Med, 42:952-962 (1999), [3] Jenkinson M, et al. Neuroimage, 17:825-84 (2002)

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