A new method for data acquisition and image reconstruction in parallel magnetic resonance imaging

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Introduction: The final step in image reconstruction in k-space-based parallel imaging techniques usually involves a sum-of-squares reconstruction. This step may result in the final image having undesired intensity modulation. Here, we propose a novel data acquisition and image reconstruction method for parallel magnetic resonance imaging. In the new method we simultaneously collect data using a coil with uniform sensitivity like the body coil or the birdcage coil in addition to localized surface coils. The uniform sensitivity coil is included in a parallel image reconstruction technique (e.g. GRAPPA [1]) as an additional coil. The reconstructed image for this coil shows uniform intensity over the field of view that is significantly better than the conventional sum-of-squares reconstruction of individual surface coils. The uniform sensitivity coil image can also be used to correct for spatial variations in the sum-of-squares image. The proposed method is tested using real MRI phantom data.

Fig. 1. GRAPPA reconstruction with an additional uniform sensitivity coil (body coil).

Methods: A parallel imaging experiment is modified by allowing simultaneous acquisition of reduced k-space datasets from both a uniform sensitivity coil and the surface coil array. The additional body coil is included in the GRAPPA reconstruction process as a regular surface coil. This approach is illustrated in Fig. 1. The image corresponding to the uniform intensity coil is expected to have a uniform intensity after reconstruction and can be regarded as the final reconstruction without the need to reconstruct other coils. Unfortunately, this body coil image may suffer from lower SNR because the coil is far away from the imaging volume. It may also suffer from reconstruction artifacts during GRAPPA reconstruction for the same reason. Therefore, the sum of squares reconstruction of all images (including uniform coil) generated from GRAPPA could be a more interesting solution with better SNR, lower artifact level and relatively inferior uniformity. Alternatively a sum-of-squares reconstruction of only the surface coils can be compensated for nonuniformity by a pixel by pixel comparison to the body coil image to obtain uniform intensity in the final image.

Experiments: The described method was applied to a real MR phantom acquired with a gradient echo sequence on a Philips 3T Achieva system. Because the system does not allow simultaneous receive of signals from the surface coil array and the body coil, two experiments were performed sequentially using the cardiac coil array with six elements and the body coil. The scan parameters were TR/TE=11/2.7 ms, FOV = 40x40 cm, slice thickness = 5 mm, matrix size=448x448. The data were then subsampled with a factor of R = 2. A set of 32 lines at the center of k-space were also retained for GRAPPA training to determine the reconstruction kernel. Image reconstruction was performed as described above. For comparison, conventional GRAPPA reconstruction was performed using the data from the six surface coils with all other parameters being identical.

Fig. 2. (A) The sum-of-squares reconstruction of GRAPPA. (B) The body coil image using GRAPPA reconstruction. (C) The correction function obtained by dividing smoothed versions of (A) and (B). (D) The intensity-corrected sum-of-squares image.

Results: The sum-of-squares image reconstructed using GRAPPA and data from the six surface coils is shown in Fig. 2A. The intensity of the image significantly decrease towards the upper edge of the image. The GRAPPA image corresponding to the body coil in the proposed method is shown in Fig 2B. Improved uniformity in intensity is evident in this image. A small residual artifact is noticed in the GRAPPA-reconstructed body coil image. This artifact may be due to the high g-factor in the middle of the image manifested by the lower SNR of the body coil signal. An intensity correction for the conventional GRAPPA image can be obtained by dividing the (smoothed) body coil image by the (smoothed) conventional GRAPPA image (Fig. 2C) to get a better image (Fig. 2D). The benefit of the uniformity of the body coil image and the high SNR of localized surface coils can be traded off in a sum-of-squares reconstruction of the whole coil data including the uniform coil as shown in Fig. 3.

Fig. 3. (A) The sum-of-squares reconstruction of GRAPPA using only surface coils. (B) The sum-of-squares reconstruction of GRAPPA using both the surface coils and the body coil.

Conclusions: The proposed method for data acquisition and image reconstruction improves image uniformity over the entire FOV at no additional cost to scan time. By overcoming the current hardware limitation in MRI systems, the proposed method will enable improved image quality in parallel imaging.

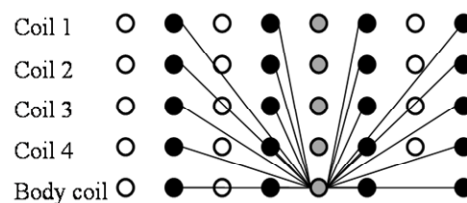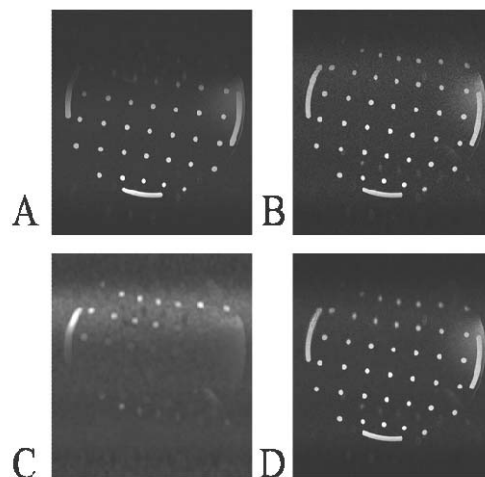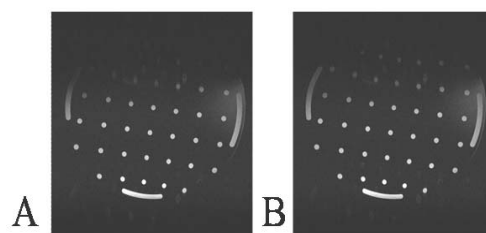**References:**

[1] M. A. Griswold et al., MRM. 47(6), 2002