Introducing Auto-Calibrated Parallel Imaging GRAPPA to 3D Axial Continuously Moving Table Whole-Body MRI

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Introduction

Continuously moving table MRI with lateral read-out [1], [2] provides very efficient k-space coverage in particular for short-bore MR systems with a limited longitudinal FOV. If in this context imaging can not be performed in free breathing, data acquisition is performed during one single breath hold. This consequently restricts acquisition time and thus spatial resolution at least when imaging in the thoraco-abdominal region of the patient. Parallel imaging, however, can be applied to increase spatial resolution due to the speed up in data acquisition while maintaining the breath holding time. In this work, auto-calibrated parallel imaging GRAPPA [3] was implemented for continuously moving table MRI with lateral readout [2], which permitted the acquisition of high-resolution data without respiratory artifacts. The GRAPPA accelerated protocol with increased spatial resolution was compared to a reference protocol in 5 healthy volunteers.

Theory

In 2006 a reconstruction method for continuously acquired data during table movement and lateral read-out was introduced which performs position correction completely in k-space [2]. This method features upsampling in the direction of slice selection and positional correction by phase twisting the acquired data. Furthermore, auto-calibrated parallel imaging proved to be feasible with continuously moving table MRI [4] if the receiving coils are fixed to the subject volume of interest and the auto-calibration lines are position corrected together with the undersampled imaging lines. Since in the reconstruction method of the present study upsampling is performed only in the longitudinal direction, GRAPPA can be performed in the anterior-posterior direction without restrictions of any kind.

Methods

Imaging was performed on a 1.5-T Magnetom Espree (Siemens Medical Solutions, Erlangen, Germany) short-bore system with high performance gradients. The scanner provides whole-body coverage with a matrix of phased-array surface coils which connect to 18 independent receiver channels. The reconstruction software in [2] was adapted to auto-calibrated parallel imaging GRAPPA. Gradient echo MR imaging (TR/TR = 4.6/2.3 ms, $\alpha = 25°$, slab thickness = 60 mm, slice oversampling 20%) was performed with slab selective axial excitation during continuous table movement (v = 10 mm/s). The imaging volume was 400 x 270 x 1620 mm^3 (read x phase x slice), which was spanned by 810 slices of 2.0 mm thickness. 192 pixels in the left-right direction were acquired during each read-out. Fully sampled data was compared with an undersampled acquisition in the anterior-posterior direction (net acceleration 1.6), which was reconstructed with GRAPPA. The speed-up in data acquisition was used to increase in-plane spatial resolution from 2.1 x 4.2 mm^2 to 2.1 x 2.7 mm^2, while the total acquisition time of 161 s was held constant. The image quality of the GRAPPA accelerated protocol and the reference protocol was compared in 5 healthy volunteers. The volunteers were advised to hold their breath while scanning the thoraco-abdominal region.

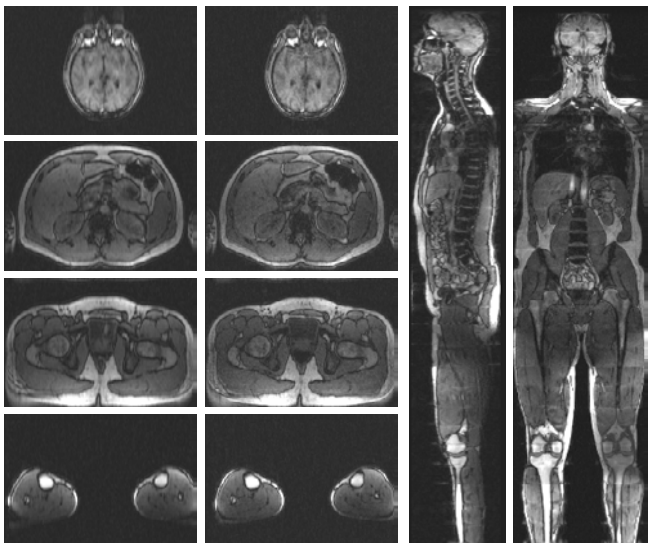

FIG. 1. Slab selective axial gradient echo whole-body MRI acquired during continuous table movement (FOVz 1620 mm, slice thickness 2.0 mm). (a) Selected axial slices of the reference protocol without parallel imaging (FOVx-y 400 x 270 mm, matrix 192 x 64). (b) Images acquired with GRAPPA and increased phase resolution (FOVx-y 400 x 270 mm, matrix 192 x 128). Due to GRAPPA accelerated acquisition the total acquisition time and thus the breath holding time was held constant. (c) Sagittal and (d) coronal reformats of the whole-body GRAPPA dataset. Increasing the phase resolution from 4.2 mm to 2.7 mm in the GRAPPA protocol markedly improved overall image quality and sharpness of anatomic display.

Results

Seamless whole-body MRI was successful in all 5 volunteers. Respiratory artifacts were neither visible in the data acquired with the reference protocol nor in the GRAPPA protocol with increased spatial resolution. Due to the increase in phase resolution from 4.2 mm to 2.7 mm in the GRAPPA protocol, partial volume effects were markedly reduced, which improved overall image quality and sharpness of anatomic display (Fig. 1). In the case of GRAPPA, residual aliasing artifacts could not be detected. While the acquisition time was held constant for both protocols, the reconstruction time, however, increased from 2:30 min to 3:45 min due to the increased computational effort of the GRAPPA algorithm.

Discussion and Conclusion

Parallel imaging in combination with continuously moving table MRI with lateral read-out proved to increase the spatial resolution while not increasing the breath holding time. Although parallel imaging in the anterior-posterior direction is straightforward, the matrix coil setup potentially allows parallel imaging additionally in the second phase-encoding direction. This, however, requires the integration of the upsampling part of the moving table reconstruction into the GRAPPA algorithm and will be part of future developments. Nevertheless, when working with state-of-the-art short bore scanners with a small homogeneous imaging volume, the proposed method could be pre-requisite for a variety of seamless large-FOV imaging applications such as whole-body tumor staging and MRI venography.

References

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