Continuous table movement MRI in a single breath-hold: Highly undersampled radial acquisitions with nonlinear iterative reconstruction and joint coil estimation

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INTRODUCTION

Continuous table movement MRI (TimCT ™) is an emerging technique for a variety of clinical applications [1, 2]. In particular, rapid short-TR two-dimensional imaging of the body in transverse orientation features optimum scan time efficiency with seamless coverage beyond the physical coronal FOV determined by the magnet and the gradient hardware [3]. Furthermore, state-of-the-art implementations support data acquisition with RF phased-array surface coils, while dynamically selecting a subset of receive coils close to the isocenter of the magnet. Although these conditions establish the basis for accelerating data acquisition with parallel imaging, the achievable acceleration factors in a clinical setting are not yet sufficient to scan an extended FOV in a single breath-hold. Radial scanning in combination with innovative iterative image reconstruction, however, promises significantly higher acceleration factors. Moreover, such methods allow for a precise calculation of coil sensitivity profiles which for continuously moving table MRI represents a unique challenge: apart from moving to a new slice position for each section, also the subset of receive coil elements might have been changed. In this work, such problems are overcome by a nonlinear iterative image reconstruction technique with joint estimation of coil sensitivities [4, 5]. A preliminary application deals with continuously moving table MRI based on highly undersampled radial acquisitions. The scan efficiency and image quality of this concept was demonstrated in 5 healthy volunteers for MRI of a large abdominal FOV in a single breath-hold.

METHODS

In the current setup, two-dimensional radial scanning was implemented in a gradient-echo MRI sequence featuring continuous table movement. To achieve sufficient acceleration of data acquisition and to allow for large FOV abdominal imaging in a single breath-hold, an iterative image reconstruction by regularized nonlinear inversion was applied which exploits the advantages of parallel imaging [4]. In this case, the image content and coil sensitivities were jointly estimated directly from the undersampled data which was expected to uniquely adress the specific requirements of continously moving table MRI. For the reconstruction of consecutive slices the regularization took advantage of the similarities to a directly neighboring slice in close analogy to a temporal regularization as described in [5]. After image reconstruction a median filter was applied to suppress residual streakings.

In- vivo experiments were performed on 5 healthy volunteers after informed written consent using a 1.5 T MAGNETOM Aera (Siemens AG, Erlangen Germany) with software release *syngo*® MR VD11D (opposed-phase gradient echoes, TR/TE 4.2/2.38 ms, flip angle 12°, bandwidth 473 Hz/Px, FOV 384x384x500 mm, 207 slices, in-plane resolution 2.0x2.0 mm, slice thickness 3.0 mm, slice overlap 20%). The acquisition of 21 spokes per slice resulted in a net acceleration factor of 9. The total acquisition time was 20 s with a constant table speed of 25.1 mm/s. For signal reception two 18 channel matrix-coils were placed anterior on the volunteers. A total of 32 elements were available for the spine array coil integrated into the table. A single coil select included a subset of 10 – 15 different coil elements depending on the body region.

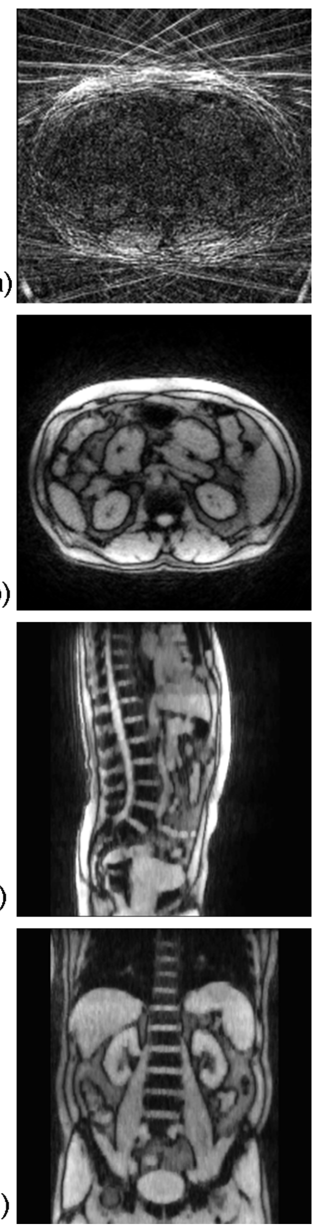
Conventional gridding reconstruction [6] was compared to iterative image reconstruction which was performed online on an Nvidia C1060 GPU (Nvidia, Santa Clara, CA, USA). In the latter case, the scale factor for regularization was selected conservatively to 0.2.

RESULTS

Single breath-hold continuous table movment MRI of the abdomen was successfully performed in all cases. Image reconstruction of a single slice using iterative image reconstruction took about 4 s. While severe streaking artifacts rendered the conventional gridding reconstruction unusable (Fig. 1 a), the proposed nonlinear iterative reconstruction succeeded to almost complete suppression of residual undersampling artifacts (Fig. 1 b-d).

CONCLUSIONS

Nonlinear iterative image reconstruction with joint coil estimation allows for high acceleration factors, while uniquely adressing the requirements for continuous table movement MRI. A reduction of the image reconstruction time, however, seems to be essential for a broad acceptance in clinical practice. Nevertheless, the robustness of the method and the image quality achieved justifies further investigation in volunteers and patients.



(a)
(b)
(c)
(d)

Fig. 1: Benefits of highly undersampled seamlessly acquired radial MRI during continous table movement: (a) While conventional gridding reconstruction causes severe image degradation, (b) nonlinear iterative image reconstruction almost completely suppresses streaking artifacts. (c), (d) Sagittal and coronal reformats of (b) show excellent image quality throughout the whole volume.

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