Compensation of Respiration-Induced Off-Resonance in Real-Time Spiral *k-t* BLAST Imaging

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Introduction

The combination of efficient *k*-space sampling strategies and fast dynamic imaging techniques permits reaching temporal resolutions in real-time imaging that eliminate most respiratory motion artifacts. This was demonstrated in abdominal imaging using a synthesis of spiral imaging and *k-t* BLAST, with which a spatial resolution of about 1 mm was attained in about 100 ms per frame [1,2]. However, free breathing leads not only to direct motion artifacts, but also to indirect field inhomogeneity artifacts through distortions of the magnetic field. In spiral imaging, the resulting blurring may be severe. A simple, approximate strategy to reduce it is proposed and explored in this work.

Methods

The tracking of dynamic changes of the magnetic field during imaging has been addressed previously [3,4]. While the suggested approaches provide a time-resolved field mapping with typically high spatial resolution, they slow down the imaging and substantially increase reconstruction complexity. The latter amounts to at least one order of magnitude in the framework of non-Cartesian *k-t* BLAST.

Therefore, a simpler, less accurate approach is proposed in this work. Variations in the phase of the low frequency *k*-space samples of the imaging data are analyzed to estimate dynamic changes of the magnetic field. Spatial resolution is partly achieved by exploiting the locality of the sensitivity of individual coil elements through a separate processing of their data. In its simplest form, this approach involves the derivation of resonance frequency offsets from changes in the phase of the central *k*-space sample over time and a subsequent, corresponding demodulation of the imaging data before their reconstruction for each coil element.

Abdominal real-time imaging was performed on volunteers on a Philips 1.5 T Achieva scanner with a segmented, variable-density spiral spoiled gradient-echo sequence and a five-element receive coil. A spectral-spatial pulse with an envelope of 1331 and a flip angle of 25° was used for a water selective excitation. The FOV was 330 x 330 mm^2 and the voxel size 1.2 x 1.2 x 8 mm^3. The acquisition was segmented into 20 interleaves, which were typically grouped into 5 subsets. Each subset took about 110 ms to sample and covered the center of *k*-space fully to provide the required training data.

Results

Selected frames from one of the acquired image series are shown in Fig. 1. Motion artifacts that are visible in the results of the sliding window reconstruction, for instance in the left kidney, are mostly suppressed by the *k-t* BLAST reconstruction. However, image quality still deteriorates dramatically from expiration to inspiration due to motion-induced field inhomogeneity artifacts. In particular the hepatic vasculature is heavily blurred. The proposed off-resonance correction essentially restores image quality in inspiration, while hardly affecting it in expiration.

The estimated temporal variation of the resonance frequency, resolved by coil elements, is plotted in Fig. 2 for 200 consecutive frames. No filtering was applied in the generation of these time series, in all of which the respiratory cycle is consistently reflected. Their considerably different amplitude underlines the benefit of analyzing the data from each coil element individually.

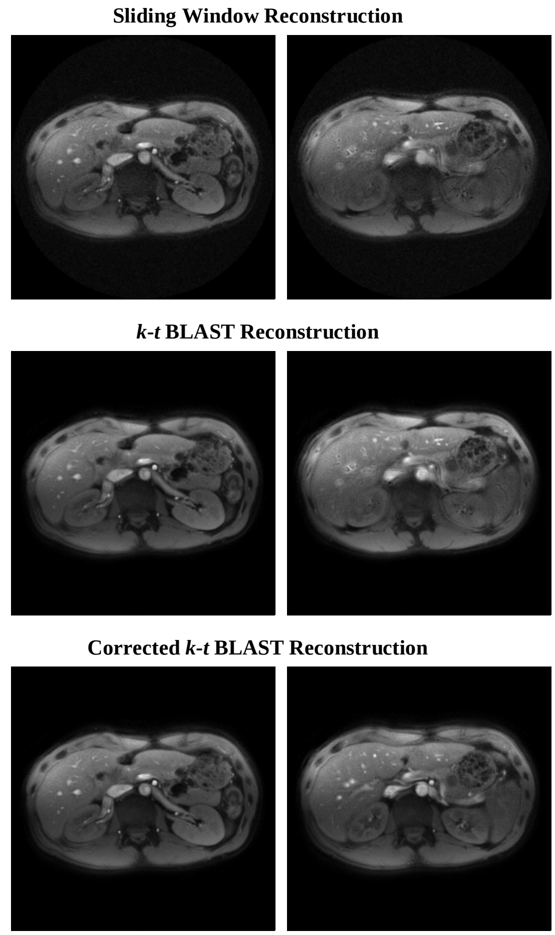

Fig. 1. Frames obtained during free breathing in expiration (left) and inspiration (right). Results of the standard sliding window and k-t BLAST reconstruction are juxtaposed with results of the proposed k-t BLAST reconstruction with off-resonance correction.

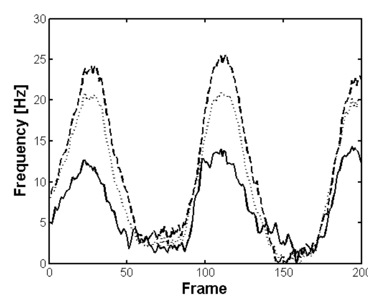

Fig. 2. Time course of the resonance frequency offsets that were derived from the low frequency k-space samples acquired with three of the five coil elements.

Discussion

Inferring information on the magnetic field from a single complex image is practically impossible due to numerous confounding factors, including image contents and coil sensitivity. Image series, however, principally allow gaining insights into temporal variations of the magnetic field, provided that their effect is either dominant or separable from other, similar effects. The presented results demonstrate that this is indeed feasible under realistic conditions.

The proposed approach permits an approximate compensation of temporal variations of the magnetic field without changes to the imaging sequence and significant increases in reconstruction complexity. The spatial resolution of the off-resonance correction may evidently be improved by using more and smaller coil elements, and by including more samples in the estimation. Both increase the risk of interference of other factors, such as flow, and, therefore, require the application of suitable filters. The obtained time series may also serve other purposes than an off-resonance correction, including a triggering, gating or tracking.

References

1. Hansen MS, et al. Magn Reson Med 2006; 55:85-91. 2. Eggers H, et al. Proc ISMRM Workshop on Real-Time MRI 2006. 3. Nayak KS, et al. Magn Reson Med 2001; 45:521-524. 4. Sutton BP, et al. Magn Reson Med 2004; 51:1194-1204.