k-t accelerated IDEAL for robust water-fat dynamic imaging

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Introduction

IDEAL (iterative decomposition of water and fat with echo asymmetry and least-squares estimation) [1] has been demonstrated successfully in a wide variety of applications. One drawback of IDEAL is the necessity to acquire images at three echo times, thereby prolonging scan time. Several solutions have been proposed to shorten the acquisition, such as by combining IDEAL with parallel imaging [2], partial Fourier acquisition [3], efficient *k*-space sampling schemes [4], and re-using field-map estimation in repetitive scanning [2].

In the context of dynamic imaging, IDEAL can also be accelerated by *k-t* methods [5-10], which exploit spatiotemporal correlations in the data to allow for sparse sampling. The combination of IDEAL and *k-t* acceleration is particularly synergistic. *k-t* methods allow for high acceleration, which more than overcomes the three-fold prolongation of scan time. In addition, the echo times used by IDEAL represent a spectroscopic axis, which can be used as an additional dimension for signal packing, in the same vein that extra spatial [6], velocity axis [7], or respiratory [8] axes can be incorporated for acceleration. In this work, we demonstrate net acceleration factors of 4.3x and 6.3x that can be achieved with this approach in the context of small-animal cardiac imaging at high field.

Methods

An IDEAL gradient-echo cine sequence [11] was implemented on a Bruker 7T BioSpec system (Bruker BioSpin, Ettlingen, Germany). Cardiac imaging was performed on rats and mice with electrocardiogram (EKG) triggering (SA Instruments, Stony Brook, NY), 10 ms per cardiac phase, variable number of cardiac phases to fit the full R-R interval, 25° flip angle, and no respiratory gating. Echo times were chosen to be the shortest that satisfied the required phase shifts. Dynamic imaging of one slice typically takes ~1 min, depending on heart rate. Full *k*-space data were acquired, and were decimated afterwards to study the effects of undersampling. For *k-t* acceleration, optimized sampling patterns at 5x and 8x acceleration [9] were used, with the central 10 phase-encode lines serving as training data [10]. *k-t* BLAST was applied to the undersampled data from all TE's as a higher dimensional dataset. Afterwards, the reconstructed images underwent IDEAL for water-fat separation.

Results

Fig. 2 shows representative results from a coronal view of a rat. The figure shows one time frame out of a cine loop of 16 frames. The inset shows a cross section profile through the heart as a function of time. Good image quality was achieved with *k-t* BLAST. As expected, the image quality was reduced at higher acceleration factors, leading to increased artifacts. Flow and respiration-related artifacts were more problematic for the reconstruction, due to the somewhat incoherent and the high "entropy" nature of these artifacts, making their signals more difficult to recover. IDEAL water-fat separation was successful in all cases throughout the cardiac cycle and at all acceleration factors.

Discussion

IDEAL is an attractive water-fat separation method. A drawback is the prolonged scan time due to the need to acquire at least 3 echo times. Dynamic imaging with IDEAL can be combined with *k-t* acceleration to reduce scan time below the nominal time for a single image. In this work, we demonstrated net acceleration factors of 4.3x and 6.3x, resulting in scan times of 70% or 47% compared to a single-average scan. The combination of IDEAL and *k-t* acceleration is favorable since the IDEAL echo times present an extra data dimension, which can be used for signal packing and acceleration.

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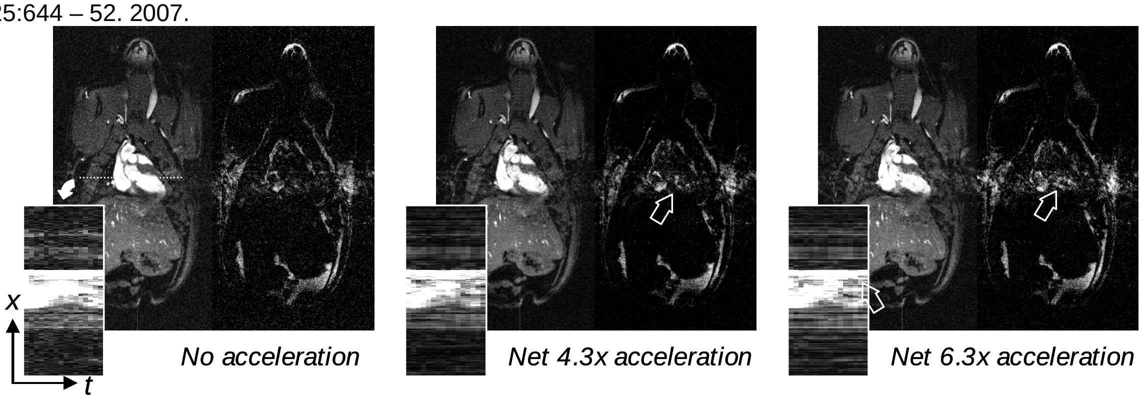

Fig.1 Representative *k-t* accelerated IDEAL images of a rat in coronal view through the heart. Open arrows point to flow- and respiration-related artifacts which were more evident at higher acceleration.