Influence of training data quality on *k-t* BLAST reconstruction

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BACKGROUND The *k-t* BLAST method[1] is a new technique for accelerating dynamic imaging. The acceleration is achieved through optimized packing of signals in *x-f* space[2,3] and by resolving any remaining aliasing in *x-f* space using prior knowledge acquired in a training stage of the acquisition. The performance (i.e. level of artifact suppression) of the method depends on the quality of the training data. The quality of the training data is determined by several parameters: a) the amount of training data, b) the spatial misregistration between the training and the undersampled data and c) the filtering of the training data prior to reconstruction. Although the optimal choice of those parameters is content-dependent to some extent, it is possible to draw general rules on how training data quality affects the reconstruction result. The purpose of this work is to identify such rules. *In vivo* cardiac images were acquired to confirm the findings.

MATERIALS AND METHODS A 2D dataset of synthetic images was generated to simulate the contracting heart inside the thorax. The images consisted of an idealized contracting sphere inside a stationary cylinder. The wall of the contracting sphere (i.e. the ventricle wall) was kept at constant volume during the contraction. One contraction of the sphere (i.e. one heart cycle) was sampled at 200 frames/cycle (TR ~ 5 ms) and simulation data sets with fewer frames were then sampled from this fully time-resolved simulation.

To investigate the dependence of the reconstruction error on the acceleration factor and the amount of training data, simulation datasets were sampled at a series of acceleration factors (1, 2, 4, 5, 8, 10) and training data were sampled with various numbers of phase-encoding lines (from two up to all lines). The diagonal elements of the covariance matrix were used in the reconstruction[1].The reconstructed images from *k-t* BLAST were compared to the original fully sampled images. The relative root-mean-square (RMS) error was calculated for each cardiac phase as the RMS difference between the original and reconstructed images normalized by the RMS intensity of the original. The impact of spatial misregistration was investigated by shifting the training data (10% phase-encode lines used) in steps of one pixel in *x*- and *y*-directions prior to *k-t* BLAST reconstruction. The same simulation also evaluated the effects of filtering the training data, using one of three schemes: 1) No filtering, 2) Hamming filter applied to the phase-encoding (k_y) direction, and 3) Hamming filter applied to both phase- (k_y) and frequency-encoding (k_x) directions. The widths of the Hamming filters were equal to the number of phase-encoding lines in the training data set. Finally, the effects of both the amount and the spatial shift of the training data were jointly investigated. This was done by shifting the training data (only in the phase-encoding k_y direction), while varying the amount of training data.

To verify the findings *in vivo*, a 2D *k-t* BLAST scan was acquired in a volunteer. The undersampled and training data were measured in two separate breath-holds, with deliberately different breath-hold positions (expiration and inspiration positions for the undersampled and training data, respectively). The amount of acquired training data was 30% of the total phase-encode lines. Reconstruction was performed with either all (i.e. 30%) or one third (i.e. 10%) of the acquired training data.

RESULTS Figure 1 shows the reconstruction error as a function of the amount of training data and the acceleration factor. The reconstruction error increased with the acceleration factor. As expected, the reconstruction error was markedly higher when the amount of training data was reduced to a minimum. The error decreased with more training data, but the reconstruction did not benefit substantially when the amount of training data was increased beyond 10 %. Figure 2 illustrates the effects of spatial misregistration between the training and the undersampled data. For the image contents examined here, misregistration in the phase-encoding direction (y) was generally worse than in the frequency-encoding (x) direction. The robustness of the reconstruction against misregistration was improved by filtering of the training data (see lower panels vs. upper panel of Figure 2). With filtering in both the frequency- (x) and phase-encoding (y) directions, the reconstruction was relatively robust against misregistration of up to 5% of the field of view. Figure 3 shows the reconstruction error as a function of both the amount of training data and misregistration in the phase-encoding (y) direction. The reconstruction became increasingly sensitive to misregistration with more training data. With lower amounts of training data, moderate spatial shifts had an insignificant impact on the reconstruction result. This finding was confirmed *in vivo* (Figure 4). The misregistration between the training and the undersampled data due to different breath-hold positions resulted in residual aliasing artifacts in the form of minor flickering. These artifacts (marked by the arrow) were more noticeable with more training data.

DISCUSSION In this work, we studied the performance of *k-t* BLAST as affected by the quality of the training data. Reconstruction error was found to remain low even with very small amounts of training data. Using more training data benefited the reconstruction by reducing the error. However, the benefit from using larger amounts of training data gradually diminished beyond 10%. On the other hand, the susceptibility to misregistration increased with more training data. Therefore, in general, the amount of training data should be in the range of 5-15% of a fully sampled dataset to get the maximal benefit from the training data while keeping the susceptibility to spatial misregistration to a minimum. These benefits in terms of lower reconstruction error and robustness against misregistration are further improved by filtering of the training data, both in the low-resolution phase-encoding direction and in the full-resolution frequency-encoding direction.

REFERENCES 1. Tsao J et al., Magn. Res. Med. 50: 1031-1042. (2003) 2. Willis NP, Bresler Y. IEEE Trans. Imag. Proc. 4: 642-666. (1995) 3. Tsao J. Magn. Reson. Med. 47: 202-207. (2002)

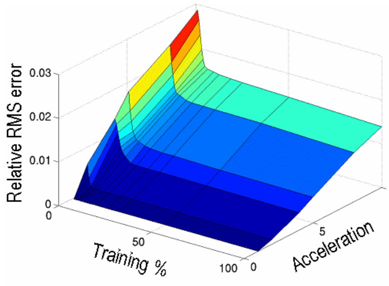

Figure 1. RMS reconstruction error vs. acceleration factor and amount of training data.

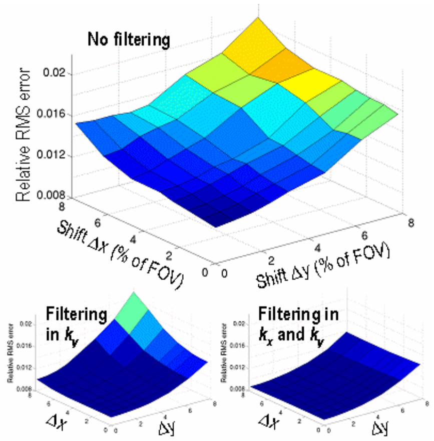

Figure 2. RMS reconstruction error vs. spatial shift of training data. Top: No filtering. Bottom left: filtering in k_y. Bottom right: filtering in both k_x and k_y.

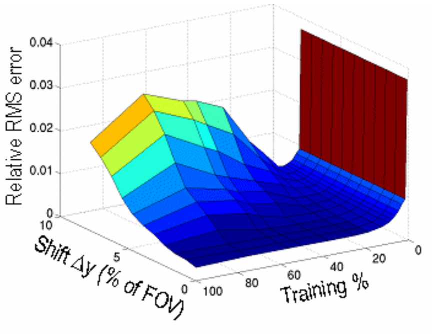

Figure 3. RMS reconstruction error vs. spatial shift of training data and the amount of training data.

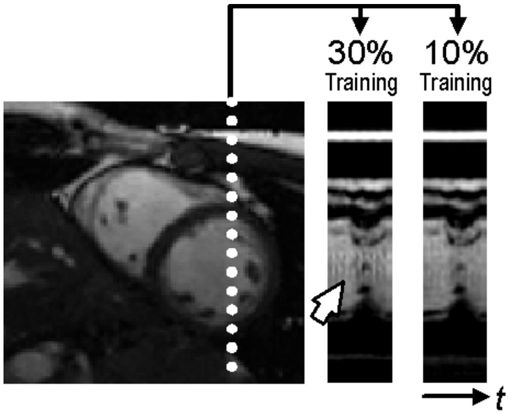

Figure 4. One frequency encoding position. Result of reconstruction with 30% (middle) and 10% (right) of misregistered training data. Arrow points to elevated artifacts with increased training.