Considerations on training data in *k-t* BLAST / *k-t* SENSE accelerated quantitative flow measurements

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INTRODUCTION In recent reports, *k-t* BLAST and *k-t* SENSE have been presented as techniques to significantly accelerate dynamic imaging [1]. These methods have also been combined with phase contrast (PC) velocity mapping, enabling single breath-hold acquisitions with high spatial and temporal resolutions [2]. The *k-t* approach is based on prior knowledge of the signal distribution obtained from a low-resolution training scan. The influence of training data quality has been investigated for cardiac cine imaging [3], but the impact on flow quantification has not yet been studied. The aim of this work was, therefore, to find the minimum amount of training data needed for reliable flow quantification and to investigate the effect of training data being plugged into reconstruction. For this purpose, computer simulations were carried out by using a subset of conventional PC reference data acquired in the ascending aorta. Furthermore, quantitative flow parameters extracted from both accelerated and conventional scans were compared for 6 healthy volunteers.

METHODS In the *k-t* approach [1], spatio-temporal correlations of the signal distribution in dynamic image series are exploited to allow for undersampling in *k-t* space (Fig.1). Potential aliasing caused by this undersampling is resolved using prior knowledge of the signal distribution. Thus, data acquisition consists of two stages, an undersampled acquisition stage and a training stage. In combination with PC measurements, the two velocity encoded segments are acquired in an interleaved manner for each stage. Each velocity segment is reconstructed separately using *k-t* BLAST / *k-t* SENSE, before creating velocity maps by calculating the phase difference (Fig. 1).

In computer simulations, a subset of fully sampled PC data acquired in the ascending aorta was used for *k-t* BLAST / *k-t* SENSE reconstruction to investigate different reconstruction strategies and the minimum amount of training data needed. The *k-t* reconstruction as described in [1] was extended such that profiles acquired in the training stage were substituted into reconstruction (denoted as '*k-t* BLAST / *k-t* SENSE plug in'). This assumes training data being acquired during the same breath-hold or in an interleaved fashion to avoid spatial displacement [3]. The root-mean-square (RMS) error relative to the reference dataset was used to quantify the performance of the different reconstruction approaches. To find the amount of training data required for reliable flow quantification, stroke volumes were evaluated from image series reconstructed with '*k-t* SENSE plug in' for acceleration factors ranging from 3 to 8 and training profiles ranging from 1 to 51 out of 168 profiles.

PC velocity maps were acquired in 6 volunteers on a clinical 1.5 T system (Philips, Best, The Netherlands) using *k-t* accelerated breath-held sequences (acceleration factors: 5 and 8, 1 signal average, breath-hold duration: 13-26 sec), as well as conventional free-breathing acquisitions with 3 signal averages to reduce respiratory motion artifacts. Scan parameters were: spatial resolution 1.3x1.3 mm², slice thickness 8-10 mm, 30-32 cardiac phases, TE/TR 2.5-3.2/5.8-6.4 ms, flip angle 10-20°, v_{max}: 120-170 cm/s. Stroke volumes evaluated for all volunteers were compared between accelerated and non-accelerated scans.

RESULTS A comparison of different reconstruction strategies is shown in Fig. 2. For an increasing number of training profiles, the relative RMS error decreases continuously for *k-t* BLAST and '*k-t* BLAST / *k-t* SENSE plug in', while the error increases slightly for *k-t* SENSE with a higher number of training profiles. The lowest reconstruction error is achieved with the '*k-t* SENSE plug in' strategy. Stroke volumes for '*k-t* SENSE plug in' at different acceleration factors are seen in Fig. 3. The deviation in stroke volume decreases with an increasing number of training profiles. For all acceleration factors, a deviation of less than 3% is achieved with more than 10 training profiles (out of 168 profiles total).

The *in vivo* results showed a good agreement between the flow curves evaluated from 5 and 8 times accelerated scans and the reference curves (Fig. 4a, 4b), although slight temporal low-pass filtering (arrow) becomes apparent for acceleration factor 8. The graphs in Fig. 4c, 4d reveal a good agreement of the stroke volumes derived from *k-t* accelerated and conventional PC data.

DISCUSSION In this work, the combination of *k-t* BLAST / *k-t* SENSE with PC velocity mapping was investigated with respect to reliable flow quantification.

In computer simulations, *k-t* SENSE with plugged in training data revealed the lowest reconstruction error, because training data are associated with low phase errors caused by eddy currents due to small phase encoding steps.

The deviation of the stroke volumes was reduced below 3% of the reference value with 10 or more training profiles out of 168. To further minimize this deviation, a trade-off between number of training profiles and breath-hold duration has to be made.

The stroke volumes estimated from *in vivo* data acquired in 6 healthy volunteers showed a good agreement between accelerated and conventional PC measurements.

PC velocity mapping accelerated with *k-t* BLAST / *k-t* SENSE is considered a promising method for high resolution breath-held flow quantification.

REFERENCES 1. Tsao J et al. Magn Reson Med 2003. 50 (5):1031-1042; 2. Baltes C. et al. Proc. ISMRM 2004, 1858 3. Hansen M. S. et al. Magn Reson Med 2004 52 (5): 1175-83

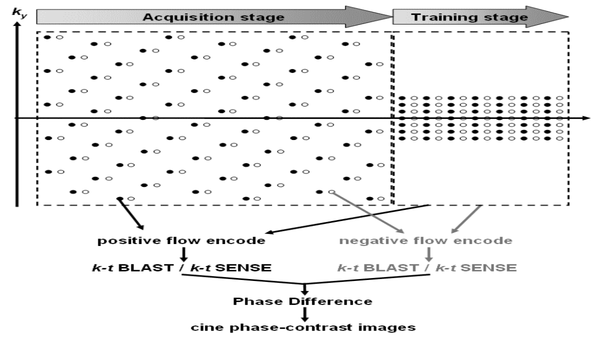

Figure 1. Data acquisition scheme for PC measurements accelerated with *k-t* BLAST / *k-t* SENSE (acceleration factor: 5).

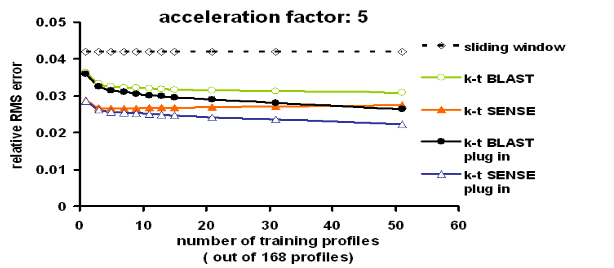

Figure 2. Relative RMS error versus the number of training profiles for different reconstruction strategies (acceleration factor: 5).

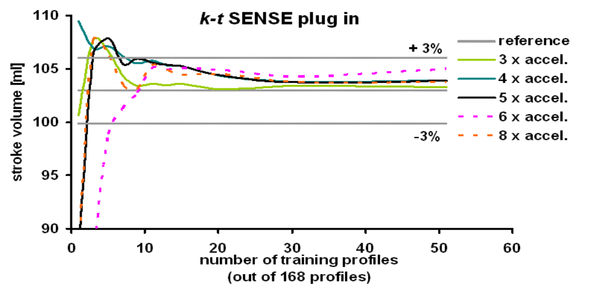

Figure 3. Stroke volume versus number of training profiles for acceleration factors from 3 to 8.

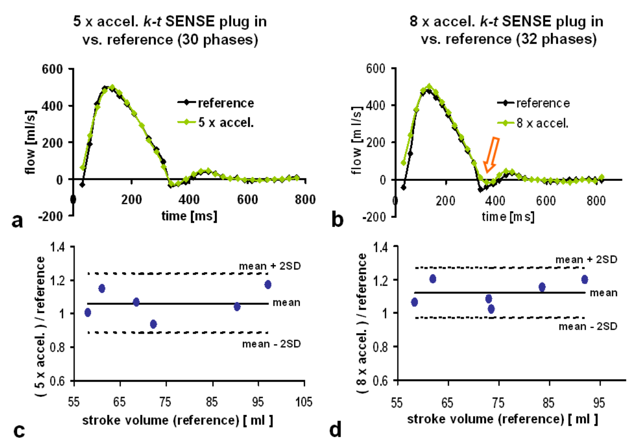

Figure 4. Representative flow curves for acceleration factors 5 (a) and 8 (b). Stroke volumes evaluated from accelerated and conventional PC velocity maps acquired in 6 volunteers (c, d).