Eight-fold Acceleration of PC-SSFP Velocity Mapping using k-t BLAST

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Introduction

A new flow quantification approach was recently proposed, combining phase-contrast velocity mapping and steady-state free precession imaging (PC-SSFP) [1]. This method provides high signal-to-noise ratios (SNR) resulting in low phase noise and clear depictions of the vessel throughout the cardiac cycle. In this work, we accelerated PC-SSFP velocity mapping up to 8-fold using *k-t* BLAST [2]. The accuracy of the method was validated by comparing *k-t* BLAST velocity data with data from standard PC-SSFP and conventional gradient echo (PC-TFE) velocity mapping in the ascending aorta of healthy volunteers. We showed that by accelerating PC-SSFP with *k-t* BLAST, it was possible to achieve single breath-hold, high-resolution SSFP phase contrast velocity mapping.

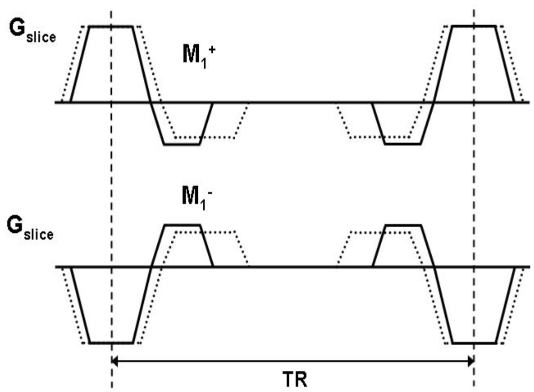

Figure 1: Slice-selection gradients for the two scan segments used in PC-SSFP. The first-order moments (M_1^+, M_1^-) are adapted to create different velocity sensitivities.

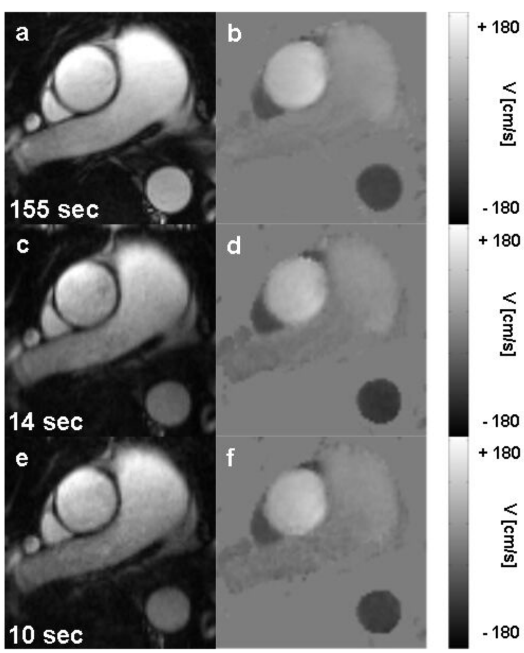

Figure 2: Anatomical images and velocity maps acquired during peak systole using PC-SSFP (**(a,b)** non-accelerated scan, **(c,d)** 5x *k-t* BLAST and **(e,f)** 8x *k-t* BLAST). For comparison, the numbers indicate the actual scan times, in which net acceleration factors (**(c,d)** 4.1, **(e,f)** 5.7) and the number of signal averages (**(a,b)** 3 **(c,d), (e,f)** 1) have to be considered.

Methods

PC-SSFP was incorporated into the acquisition software of a Philips 1.5T MR system. Through-plane velocity sensitivity in SSFP imaging was adapted by changing the first order moments of the slice-selection gradient (Fig. 1). The slice-select gradient was inverted in one of the two measurements required for phase contrast (PC) velocity mapping [1].
To shorten scan times, PC-SSFP was combined with the *k-t* BLAST method [2]. This method sparsely samples *k-t* space, thereby densely packing signal replicas in the reciprocal *x-f* space. During reconstruction, the aliasing is resolved using knowledge from low-resolution training data. The sparsely sampled high-resolution data and the low-resolution training data were acquired in a single breath-hold. Training data consisted of 11 profiles sampled at the full field-of-view.
Cine velocity mapping was performed in the ascending aorta of four volunteers. The following scan parameters were used for PC-SSFP: spatial resolution: 1.2x1.2mm^2-1.3x1.3mm^2, venc:150-180cm/sec, TE/TR:1.8-2.0ms/3.6-4.0ms, temporal resolution:19-28ms. Parameters for PC-TFE were: TE/TR:2.5-2.8ms/5.7-6.0ms, temporal resolution:23-24ms. For validation, non-accelerated PC-SSFP and PC-TFE scans were acquired as reference. These scans were acquired in a free-breathing mode, due to their long duration. Three signal averages were used to suppress respiratory motion artifacts. Scan time for the non-accelerated PC-TFE and PC-SSFP acquisitions was 4min:30sec and 2min:35sec, respectively. Using *k-t* BLAST, PC-SSFP was accelerated 5- and 8-fold. Scan time was reduced accordingly to 14 and 10sec, making single breath-hold acquisitions possible. Taking into account the acquisition of the training data, the net acceleration factors amounted to 4.1 and 5.7, respectively.

Results

Figure 2 shows anatomical images and phase maps of the ascending aorta during peak systole. Data were acquired using PC-SSFP with no acceleration (3 signal averages) (2a,2b) and acceleration factors 5 (2c,2d) and 8 (2e,2f). Excellent image quality was obtained in all PC-SSFP scans.
The flow profiles calculated from non-accelerated, 5-fold and 8-fold accelerated PC-SSFP scans compared well to the non-accelerated PC-TFE scan (Fig. 3a). The error in stroke volume between the accelerated scans and the mean of the non-accelerated PC-SSFP and PC-TFE scans was less than 9 % on average (Fig. 3b).

Conclusion

We showed that PC-SSFP in combination with *k-t* BLAST allows for accurate flow quantification at high spatial and temporal resolutions in a single breath-hold. The high intrinsic signal-to-noise ratio in PC-SSFP imaging provides favorable conditions for considerable acceleration of cine velocity mapping.

References

[1] Markl M, et al.MRM;**49**:945-952,2003
[2] Tsao J, et al.MRM;**50**:1031-42,2003

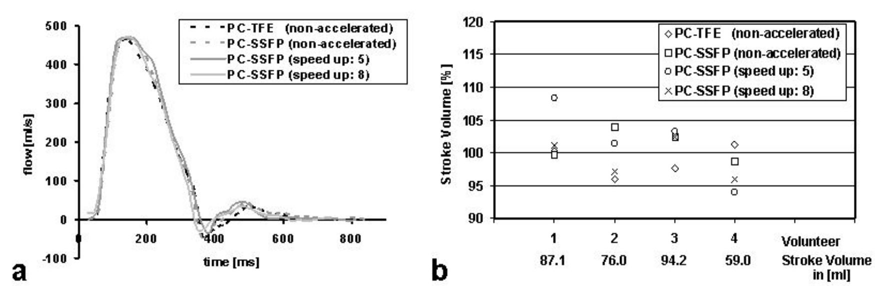

Figure 3: (a) Comparison of the flow profiles calculated from PC-TFE and PC-SSFP scans. **(b)** Stroke volumes in percent compared to the mean of the non-accelerated PC-TFE and PC-SSFP scans.