The use of k-t BLAST for measuring velocities in stenotic vessels with phase-contrast MRI

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Introduction

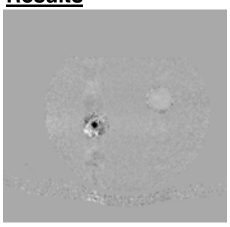
Blood flow peak velocities in constricted vessels is of considerable interest for determining stenotic pressure gradients in e.g. aortic valves and extracardiac conduits [1,2]. Phase-contrast (PC) or velocity mapping MRI, as well as Fourier Velocity Encoding (FVE) [3], offer possibilities for peak velocity determination. To measure velocity accurately with PC MRI, high spatial resolution and short TE is desirable to reduce partial-volume effects and effects of intra-voxel dephasing. However, increased spatial resolution results in longer acquisition times. Furthermore, FVE using conventional sequences in combination with sufficient velocity resolution is very time-consuming. A way to speed up dynamic sequences is the use of k-t BLAST (k-t Broad Linear Acquisition Speed up Technique) [4], which enable an undersampling of k-space, resulting in foldover artifacts. By using training data, the artifacts can be resolved. By using k-t BLAST in PC measurements, higher spatial resolution may be obtained in a reasonable acquisition time, thus opening two different possibilities for precise velocity determination in stenotic flow fields. Similarly, the use of k-t BLAST in combination with FVE significanty reduces acquisition time [5].

In this work we investigate if k-t BLAST together with high-resolution PC-MRI can accurately determine the flow velocity in a highly constricted tube phantom, within reasonable acquisition times.

Materials and Methods

A phantom with two parallel perplex tubes (d=2.11 cm), one containing an artificial stenosis (open diameter=5.9 mm, 92 percent area reduction), was used. Tap water was pumped in F->H direction through the stenosis (H->F direction in the open tube). The flow rate was constant in time, and 7 different flow velocities were used. After imaging, the flow was measured manually with timer and beaker and nominal mean velocity in the open tube was calculated using the known tube area. In the stenotic tube, nominal velocity was estimated from manually measured flow, assuming a plug-flow like velocity profile over the whole orifice of the stenosis. Two identical PC-MRI measurements (except for V_{ENC}-value, TE and slice thickness) were carried out to optimise SNR in the velocity maps for the stenosis and the open tube, respectively. PC-MRI mean velocity in the open tube and in the stenosis were determined using a large ROI encompassing the open tube and a small ROI placed centrally in the stenotic orifice, respectively. The scanner used was a Philips Achieva 3 T MR scanner (Philips, Best, The Netherlands) with a six-channel cardiac coil, and a phase-contrast fast field echo (PC-FFE) sequence with V_{ENC}=1000 cm/s and 800 cm/s, a voxel size of 0.5×0.62×7 mm and 0.5×0.62×4 mm, TE/TR=3.3/30 ms and 2.5/30 ms, NSA=1, 30-32 heart phases and k-t acceleration factors equal to 0 (no acceleration),2,5 and 8. For the measurements in the large tube, V_{ENC}=60 cm/s was used.

Results



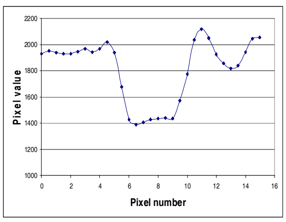
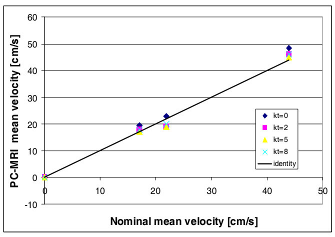


Figure 1 and 2. Phase image of the phantom (acc. factor of 5) and a corresponding smoothed velocity profile of the phantom stenosis

The results from the PC measurements with constant flow confirm a flat flow profile through the artificial stenosis. Good linearity between the MR measured velocity and the nominal velocity is seen in the open tube for all acceleration factors (figure 3). In the stenosis, linearity is maintained although the measured velocities tend to be overestimated with increasing flow velocities (figure 4). In table 1, comparisons between k-t=0 and k-t=2,5 and 8 for all investigated stenotic velocities are made. As seen from this table, deviations are less than 15% except in the most extreme velocity case (5.6 m/s) and using the highest acceleration factor.



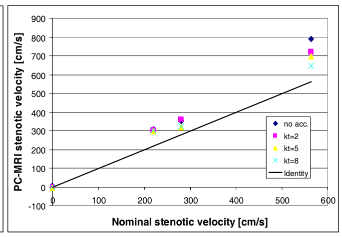


Figure 3 and 4. Measured mean velocities compared to nominal flow velocities in the tube (V_{ENC}=60 cm/s) and in the stenosis (V_{ENC}=1000 cm/s), respectively

Conclusions

The results indicate the possibility to measure velocity in severely restricted vessels by a high-resolution FFE-sequence, and to use k-t BLAST to reduce acquisition time. Increasing k-t factor did not systematically increase the deviation compared to conventional PC-imaging with no use of k-t BLAST for physiologically relevant peak velocities. In this simple phantom model, a slight overerestimation of the stenotic velocity with higher flow was seen for all k-t factors, including when k-t BLAST was not used. Further work will involve pulsating flow measurements and in vivo evaluation.

Table 1. Percent difference between PC-MRI velocities obtained with and without acceleration factor in the stenosis

	Nominal stenotic velocity [cm/s]						
k-t factor	564	281	220	181	105	94	69
2	-8.4	2.7	-2.3	-9.1	-3.4	5.3	0.4
5	-11.7	-9.0	-4.5	-6.6	-13	-2.4	-0.9
8	-18.2	-7.3	-1.9	-9.5	-7.5	1.4	1.7

References

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