Velocity mapping in highly stenotic tubes by the use of short-echo spiral acquisitions

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Introduction

Measurements of blood peak velocities in stenotic blood vessels are of clinical importance, since the peak velocity can be used to calculate stenotic pressure gradients, and thus allow estimation of the severity of the occlusion [1,2]. Phase-contrast MRI (PC-MRI) is an MR technique often used for peak velocity mapping in blood flow fields. However, as stenotic vessels often presents complex flow patterns, short echo times are needed in order to reduce effects of higher order motion and intra-voxel phase dispersion [3,4]. Nayak *et al* proposed a spiral sampling scheme to reduce echo time as well as acquisition time, and showed that spiral acquisition is suitable in mapping stenotic flow jets [5]. In this work we have compared three sequences: a short-echo-time gradient echo sequence (GRE) with spiral readouts, a k-t BLAST accelerated GRE-sequence (k-t factor of 5) and a regular GRE-sequence to investigate if a spiral sequence could be used for peak velocity and flow volume estimation with approximately the same imaging time as a k-t BLAST accelerated sequence.

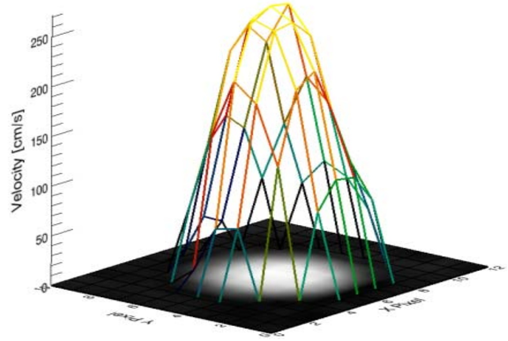

Figure 1. Velocity surface example from a spiral image, indicating a parabolic velocity profile in the stenosis centre.

Materials and Methods

A phantom with two parallel perspex tubes (d=21.1 mm), one containing an artificial stenosis (open diameter=5.9 mm, 92 percent area reduction, 6 mm length), was used. Tap water doped with Gadovist® was pumped in H->F direction through the stenosis. Four different constant flow velocities were used. A Philips Achieva 3 T MR scanner (Philips, Best, The Netherlands) with a six-channel cardiac coil was used. For all three sequences, V_{ENC}=800,400,300 cm/s and 50 cm/s, a voxel size of 1×1×7 mm, NSA=1 and 30-32 heart phases was used. Spiral sequence parameters were TE/TR=1.15/7.2 ms, 70 interleaves, and 4 ms acquisition window. GRE sequence parameters were TE/TR=2.1/30 ms. For the Cartesian sequences, k-t acceleration factors equal to 0 (no acceleration) and 5 were used. The imaging time for the conventional GRE sequence was 8 min 54 s, 2 min 5 s for the k-t BLAST accelerated sequence, and 1 min 16 s for the spiral sequence. The images were evaluated using an in-house IDL application (ITT Corporation, Colorado Springs, USA) and with the operator console at the scanner. Flow in the stenosis was measured using a ROI matching the size of the stenosis. Peak velocities were estimated as average velocity in a small (12 mm^2) ROI in the stenotic centre. These peak velocities were multiplied by a theoretically obtained factor of 2/3 to obtain the average velocity in the stenosis, assuming a parabolic velocity distribution evident from Fig.1. The two velocity measures were compared to the nominal average velocity, obtained by dividing flow (measured by timer and beaker) with the known stenosis area.

Results

The cartesian sequences suffered from signal displacements at higher flow velocities. This was not observed in any of the spiral images. In spite of this, the velocity profiles of all sequences with constant flow indicated a parabolic velocity profile in the stenosis (Fig.1). Measured flow corresponded well with the nominal flow (Fig. 2a). Peak velocities could be acquired with all three sequences, and were in agreement. Measured peak velocities were, however, seen to deviate from the nominal average velocity with increasing nominal flow, indicating that the velocity profile could not be treated as a plug-flow profile (Fig. 2b). The parabolic mean velocity (derived from the measured maximum velocity) agreed well compared to the nominal velocity (Fig. 2c), giving indirect evidence for a correct peak velocity measurement, assuming parabolic flow. Initial comparison in a healthy volunteer confirms the suitability of spiral imaging with respect to in-vivo signal-to-noise ratio.

Conclusions

The spiral sequence seems to be more robust at higher flow velocities, most probably because of the lower echo time. In conclusion, our spiral acquisition sequence corresponds well with both conventional GRE sequence and a k-t BLAST accelerated GRE sequence with respect to peak velocities and flow rates, offering peak velocity estimation at nearly half of the acquisition time of a k-t BLAST accelerated sequence.

References

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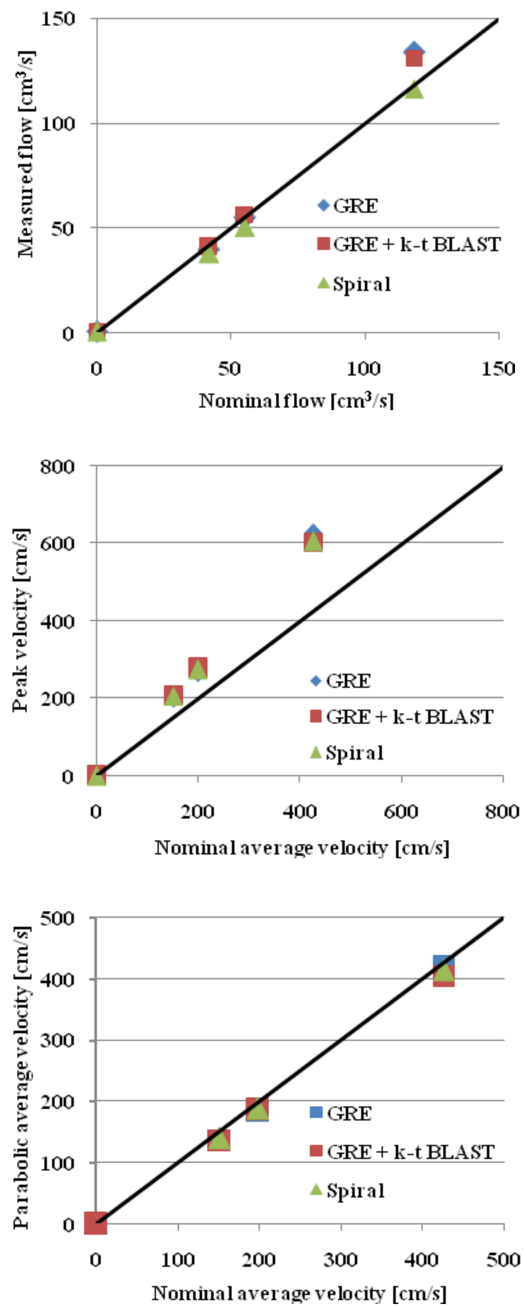

Figure 2. (a) Measured flow compared to nominal flow. (b) Peak velocity compared to nominal average velocity. (c) Parabolic average velocity compared to nominal average velocity. Solid lines represent lines of identity.