

Comparing spiral, FAcE and gradient echo sequences for high resolution velocity measurement in the carotid artery

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Introduction

Measurement of velocity distribution in regions with complicated hemodynamic conditions is difficult, because the fluctuating velocities corrupt the phase of the magnetization and can cause partial or complete signal void. In particular, for acquisition with high spatial resolution and, accordingly, long echo times, this can be a severe problem. Because hemodynamically related vessel diseases often develop in such regions (1), the exact velocity distribution is important.

We have compared three methods for high resolution assessment of velocities in the common carotid artery and the carotid bifurcation. These were the standard gradient echo (FFE), the FID-Acquired-Echo (FAcE) (2) and the spiral scan method. With all sequences, the phase contrast velocity mapping method was used.

Material and Methods

All measurements were obtained with a Philips NT 1.5 T scanner equipped with 21 mT/m, 105 mT/m/ms gradients, the CPR6 and INCA cardiac research software and, in addition to the commercial sequences, the FAcE and spiral scan sequences. Images from both of these were reconstructed by dedicated off-line software.

The scans were ECG-triggered prospectively and acquired with a 256 matrix on a 64 mm FOV. The slice thickness was 3 mm, VENC was 90 cm/sec and the gradients were flow compensated. A surface coil with a diameter of 50 mm was used. For the FAcE sequence the positive and negative velocity encodings were interleaved, i.e. acquired in the same heart cycle. The spiral scans were acquired with 60 spiral interleaves and the read-out time was 20 ms. The remaining parameters are given in Table 1.

	FFE	FAcE	Spiral
Pixelsize, mm	0.25	0.25	0.25
TE, ms	10.8	3.4	3.3
Heart phase int, ms	36	36	36
Bandwidth, kHz	114	25	54
Scan time, min:sec	8:34	8:34	2:02

Table1. Most important scan parameters.

The through-plane velocity component was acquired across two measurement planes in seven young volunteers. The planes were positioned immediately downstream of the carotid bifurcation and in the common carotid artery 20 mm upstream from the bifurcation.

The average flow through both the internal and external carotid arteries measured at the bifurcation position with all three sequences was compared with the average flow measured at the common carotid artery position. The data from the common carotid artery position was considered the "true" value. Because of signal void in the FFE data, these were excluded from the "true" values. In addition, the signal-to-noise ratio (SNR) in the modulus image (mean value inside the vessel divided by the background standard deviation) and the velocity-to-noise ratio (VNR) (mean velocity value in the vessel divided by the velocity standard deviation in stationary tissue) were calculated.

Results

Severe signal void was seen in the FFE scans, in particular at the carotid bifurcation (Fig. 1). The error in flow measured at the bifurcation compared with the "true" values were $-7.7 \pm 12.4\%$ for FFE, $-2.3 \pm 9.2\%$ for FAcE and $-16.5 \pm 7.0\%$ for the spiral sequence. The SNR was highest for the FAcE sequence and had comparable values for the FFE and spiral sequences (Fig. 2). Also, the VNR values were highest for the FAcE sequence and were slightly better for the spiral compared with the FFE sequence.

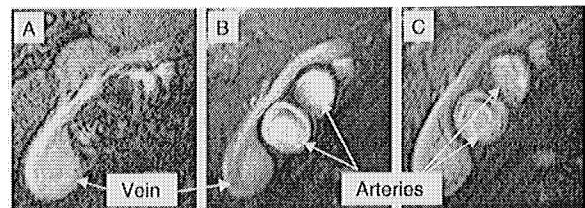


Figure 1. Modulus images from the carotid bifurcation acquired with A) FFE, B) FAcE and C) the spiral sequence.

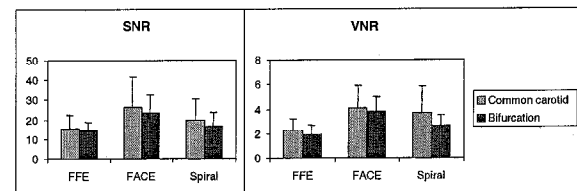


Figure 2. Signal-to-noise ratios (SNR) and velocity-to-noise ratios (VNR) for all scan methods at both measurement positions. The graphs show mean and standard deviations. Because of varying distances between the arteries and the coil the inter-volunteer deviation was high. Paired *t*-tests showed a significant difference only between the FFE and spiral values.

Discussion

By interleaving the two scan segments for the FAcE sequence, the total scan time for the FFE and FAcE scans were the same. The difference in read-out time for the two sequences allowed an almost equal temporal resolution. The bandwidth was kept as broad as possible for the FFE sequence in order to reduce the echo time. Initial pilot studies showed that this was the best compromise between SNR and signal-void. For the FAcE sequence, on the other hand, TE does not increase with reduced bandwidth, and, hence, in this case the bandwidth was selected as narrow as possible. The difference in bandwidth for the two sequences is reflected in the resulting SNR values.

The number of spiral interleaves was selected high enough for the read-out time to be kept below 20 ms in order to suppress field inhomogeneity blurring. The total scan time was only one fourth of the scan time for the other sequences. Hence, if four signal averages were used, the SNR is expected to be higher than for the FAcE sequence.

In conclusion, the study has shown that both the FAcE and spiral sequences have considerably better properties for high resolution velocity acquisition in complicated flow regions than the FFE sequence. Both FAcE and spiral scanning can be acquired without considerable signal-void in the carotid bifurcation, even in systole. The spiral sequence, however, is much faster than FAcE with only slightly reduced SNR and VNR.

References

- Pedersen EM, Oyre S, Agerbæk M, Kristensen IB, Ringgaard S, Boesiger P, Paaske WP. Distribution of early atherosclerotic lesions in the human abdominal aorta correlates with wall shear stresses measured in vivo. *Eur J Vasc Endovasc Sur* 1999; 18:328-333.
- Ringgaard S, Oyre S, Flaagoy H, Stokholm R, Pedersen EM. Velocity quantitation in arteries using individualized and automated variable velocity encoding (VENC) for each heart phase. *Proceedings of ISMRM 1999*; p2024.