Are there general protocol parameters to reduce velocity offsets? A multi-vendor study.

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Introduction: Velocity offsets caused by eddy currents are of great concern for accuracy in cardiovascular flow quantification measurements like cardiac output, regurgitation, and shunt flow [1]. Gatehouse et al. [2] pointed out that there is a need for optimized acquisition protocols to minimize the velocity offsets (<0.6 cm/s) for these sensitive cardiac applications. This pilot-study investigates whether variation of general protocol parameters across different manufacturers can reduce this offset. Parameters which have an influence on the bipolar velocity encoding gradients or on the timing between these gradients and read-out were considered.

Method: Measurements were performed on a large uniform stationary phantom. The fluid was allowed to settle down for at least 5 minutes before the first measurement. The basic breath-hold flow quantification protocol was the same as used by Gatehouse et al. [2]: TR 6.0±0.6 ms (depending on scanner type and image orientation), TE 2.9±0.1 ms, concomitant gradient correction, retro-gated cine, throughplane Venc 150 cm/s, SLT 6 mm, FOV 320x320 mm, uninterpolated pixels 1.25(FE)x2.5(PE) mm, bandwidth 355 Hz/pixel, 6 rawdata lines per cardiac cycle, no cine data-sharing or parallel imaging. Measurements were obtained in transverse, aortic (T>S -45°), and pulmonary vessel (T>C 45°) orientation. Several parameters related to gradient switching or timing were varied to identify correlations with the velocity offset: gradient speed, read-out bandwidth, partial echo, venc, and slice thickness.
These relationships were studied in five 1.5T scanners of three different types: GE Signa Excite (2x), Philips Achieva (1x), and Siemens Avanto (2x). All velocity images were reconstructed without further offset correction (which would perform unrealistically well in a large uniform phantom). The largest absolute mean velocity offset in cm/s (over a 30 mm diameter ROI) anywhere within 50 mm (for transverse and aortic) or 70 mm (for pulmonary) in-plane from the magnet iso-center was recorded for each scan (i.e. covering the region where cardiac outflow ROIs are usually placed). All the results were averaged per scanner type and normalized to the basic transverse measurement of each scanner to highlight the influence of parameter changes as a relative difference.

Results: Gradient speed change to a lower setting did show a reduction on scanner type C, and in some orientations on the other scanners (Figure 1 left). Switching partial echo off did result in a reduction of offsets on scanner C but an increase on scanner A (Figure 1 middle). Bandwidth, Venc (Figure 1 right as an example) and slice thickness changes did not show a large effect on the velocity offsets. The only general effect across vendors is the effect of slice orientation; a transverse slice gave generally lower offsets than any oblique orientation. Offsets in the pulmonary slice were often considerably larger than in the aortic.

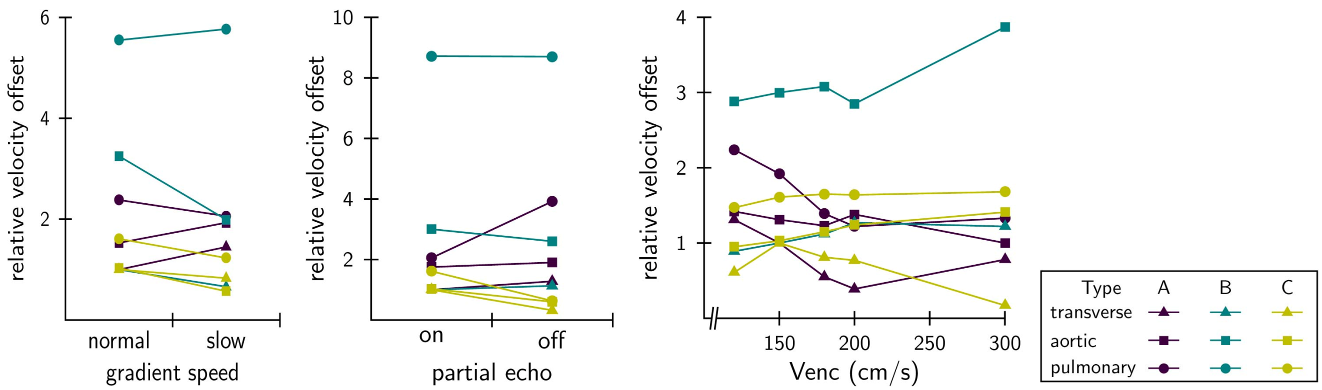

Figure 1. Relative velocity offsets as a function of several protocol parameters. Left: Scanner types B and C showed a reduction of velocity offset with slower gradient speeds. Middle: Scanner type A had lower offsets with partial echo on, whereas type C had lower offsets with partial echo off. Right: There was no correlation of velocity offsets with Venc.

Discussion: Gradient speed and partial echo did show clear effects on the velocity offset, other parameters were not of significant influence. Overall this study did not yield general guidelines across vendors by which velocity offsets of flow quantification sequences can be minimized. Therefore, protocol optimization would have to be performed on a per vendor and per protocol basis. Apart from protocol parameters, slice orientation is of major influence on the velocity offsets. This is probably consistent with the general advice to scan at minimal z-offset; if the vessel-of-interest can be positioned in the z=0 plane the offset may be further minimized. (Dieringer, Berlin personal communication of data supporting this). Therefore, as mid ascending aortic flow usually passes almost perpendicularly through a transverse slice, accurate total aortic flow may be measurable without further offset correction. Due to the typical obliquity of the pulmonary trunk, and its distance from the isocenter, offset correction is likely to be needed for pulmonary flow measurements. These findings are based on the sites tested so far: the study is on-going.

References: [1] Kilner P.J. et al. JCMR;9:723, [2] Gatehouse et al. ISMRM 2009:325