

# Volumetric Phase Contrast Flow Imaging with Multiple Station Isocenter Acquisition Substantially Improves Flow Results

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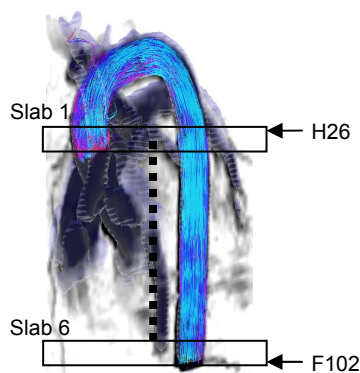
**Introduction:** For the assessment of complex flow patterns, vector-encoded MR phase contrast acquisitions with volumetric coverage are gaining interest. Besides the longer acquisition times the method is more prone to error, as a larger volume of interest is covered and the distortions due to eddy currents and gradient non-linearities increase with distance from the isocenter. A new scan method is presented that acquires the volumetric dataset in multiple z-isocentered steps. This results in substantially altered flow and peak velocity values and at the same time allows for a cross-slice background phase correction for improved robustness of the method.

**Material and Methods:** Phase contrast vector-encoded flow measurements (TR 56ms, 5mm slices, with 20% overlap, 2x3 mm in-plane resolution, PAT 2, free breathing, retrogated ECG triggering, VENC 150 cm/sec, z coverage 256 mm, scan duration ~21 mins) were performed with a 3T clinical MR scanner (Siemens MAGNETOM Verio) on healthy volunteers (n=3) in axial slice orientation, either in a single slab (48 slices) with fixed table position centered to isocenter (fix tp) or with moving table, where the slab was isocentered for every subset of 8 slices (iso tp)(see fig.1). A linear background phase correction (bpc) based on a fit through stationary pixels [1] was calculated inline for each slice separately. The resulting corrected flow images and the influence on the flow quantification results of the descending aorta and flow field visualization were analyzed. The variation of the resulting bpc across slices was investigated for the iso tp and fixed tp approach. In total, 4 different scenarios were analyzed: fix tp and iso tp, both with and without bpc.

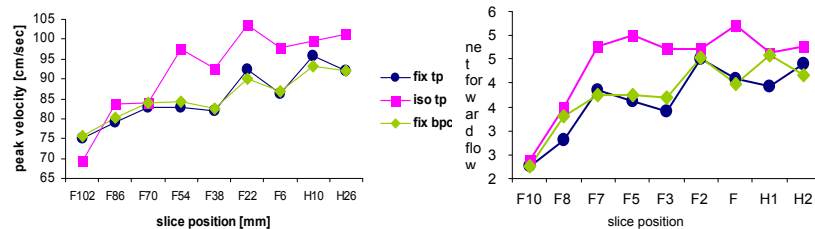
**Results:** A flow field visualization of the aorta based on the iso tp acquisition method is shown in fig. 1 [4D Flow tool, SCR Princeton]. The resulting flow parameters in the descending aorta at various z positions for the different approaches are shown in fig. 2. The effect of iso tp vs. fix tp on the flow vector field in the descending aorta is shown in fig. 3. The iso tp approach results in an overall increase of peak velocity estimates and flow values (see fig. 2). Over a wide range of z offsets (analyzed z=F70mm to H26mm) the isocenter approach results in more stable results (standard dev. forward flow 2.03 ml/sec, average forward flow 53.4 ml/sec, peak velocity 95.2 cm/sec), whereas in the fixed position scan a larger variability and overall underestimation was found (stdev forward flow 3.92 ml/s, average forward flow 44.7 ml/s, peak velocity 85.3 cm/sec). The background phase correction does not result in a significant reduction of the underestimation. The pixelwise standard deviation of the correction matrices across slices for fix tp was 1.76 cm/sec whereas for iso tp it was only 0.61 cm/sec, implying that calculation of an averaged correction map for all table positions is valid and can be used to improve the robustness of the image-based bpc.

**Discussion:** Volumetric vector flow imaging can provide additional information compared to simple 2D through-plane flow imaging. The presented method shows a significant gain in flow accuracy, in particular a systematic underestimation of flow parameters is significantly reduced over a large range of z positions. New developments in scan acceleration will enable a speed-up of this type of scan to clinically acceptable scan durations. The image based bpc does not correct for other effects than linear background phase errors due to eddy currents. The results indicate that further corrections like gradient non-linearity corrections in the velocity-encoding direction are needed to stabilize the results in volumetric flow measurements. The results also imply that the image-based background phase correction as described in [1] is not dependent on the particular anatomy, but rather on the position of the slice relative to the isocenter. This can be used to calculate a cross-slice background phase correction if the anatomy does not allow an individual calculation for each slice.

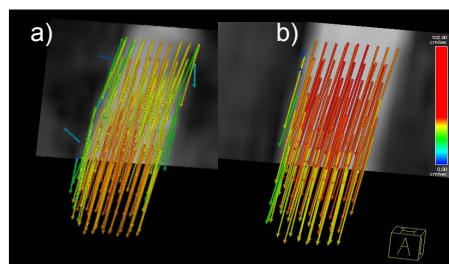
**References:** [1] Lankhaar et al J Magn Reson Imaging. 2005 Jul;22(1):73-9.



**Figure 1:** Flow field visualization of the aorta from volumetric vector flow dataset (colors inverted). In iso tp mode, the slabs were isocentered individually, whereas for the fix tp mode all slices were acquired at the same table position. The slab positions are indicated for reference.



**Figure 2:** Net forward flow and peak velocity values through the descending aorta at different z levels. The fixed table approach (fix tp) results in an underestimation of peak velocity and flow, also after background phase correction (fix bpc).



**Figure 3:** Local vector field visualization of flow in the descending aorta around z=70mm (foot) for a) fix tp and b) iso tp scan approach. Apparent peak velocities are clearly higher in iso tp mode.