Multi-Venc measurement of phase contrast MRI for improving accuracy of velocity field

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TARGET AUDIENCE: Researchers who employ phase-contrast magnetic resonance imaging (PC-MRI) technique for the purpose of hemodynamic analysis will be interested to this study.

PURPOSE: The present work aims to improve accuracy and decrease noise level of 4D phase-contrast magnetic resonance imaging (PC-MRI) data by employing multiple velocity encoding (VENC) parameters, and to investigate their advantages and limitations of multiple VENC measurements for obtaining precise hemodynamics features of blood flow.

METHODS: A 4D PC-MRI sequence with five different VENC values was employed to measure three dimensional flow field in a stenosis flow phantom. The velocity field evaluated from a larger VENC value was combined with that from a smaller VENC value, unless the velocity data are lost by phase-aliasing or phase dispersion. Improvement of accuracy and noise of the combined velocity field was compared as the overlapped number of VENC increases. Additionally, velocity fields from single and multi-VENC measurements were statistically compared by Wilcoxon signed rank test.

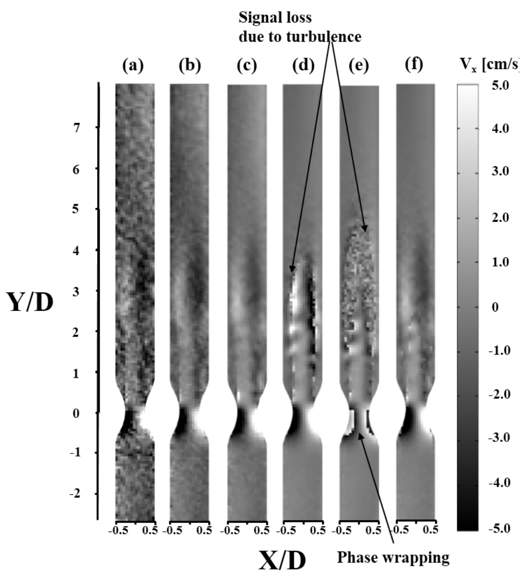

Figure 1 Radial velocity distribution through the stenosis model measured at VENC = (a) 300 cm/s, (b) 100 cm/s, (c) 50 cm/s, (d) 10 cm/s and (e) 5 cm/s. Since peak radial velocity at the stenosis apex was reached around 8 cm/s, phase aliasing only appears at (e). (f) Radial velocity distribution after multi-VENC overlapping. Due to the signal loss from turbulent flow, signal loss due to phase dispersion was observed at the post-stenosis region of (d) and (e).

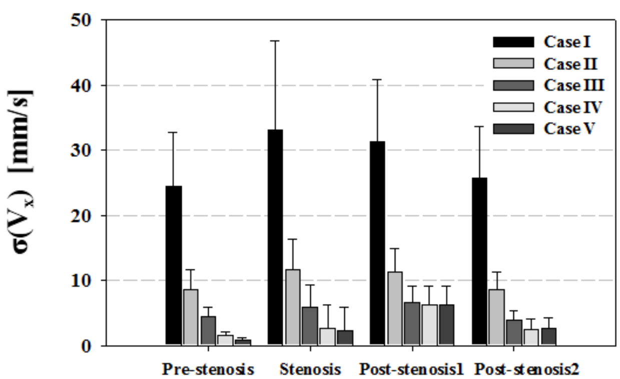

Figure 2 Effect of multi-VENC overlapping on noise levels of the radial velocity through the stenosis model. (Case I) axial velocity distribution at VENC 300 cm/s, (Case II) additional overlapping of VENC 100 cm/s with Case I, (Case III) additional overlapping of VENC 50 cm/s with Case II, (Case IV) additional overlapping of VENC 10 cm/s with Case III, (Case V) additional overlapping of VENC 1 cm/s with Case IV. Note that the regions of interest are classified into four sub-groups: pre-stenosis ($-2.5<Y/D<-1.0$), stenosis ($-1.0<Y/D<1.0$), post-stenois1 ($1.0<Y/D<4.0$) and post-stennosis2 ($4.0<Y/D<7.5$).

RESULTS: Figure 1 shows radial velocity distributions of the flow through the stenosis model. They were measured at various VENC from 5 to 300 cm/s. The velocity at the inlet and outlet region of the stenosis is around zero. Since the velocity-to-noise ratio (VNR) of PC-MRI sequence is inversely proportional to the VENC parameter, the velocity field measured with high VENC parameter (300 cm/s) shows relatively high noise level. As the VENC parameter decrease, the velocity field has higher accuracy with less velocity fluctuations. However, signal loss has been observed at the post-stenosis region due to turbulence-induced phase-dispersion. The velocity field from larger VENC parameter was combined with that of smaller VENC unless the velocity data are lost by phase-aliasing and phase dispersion. As figure 2 shows, the multi-VENC overlapping significantly decreased standard deviations of the velocity fluctuation by reducing the noise level of the velocity measurements ($p<0.05$), which resultantly contributed for more than a four-fold gain in velocity-to-noise ratio (VNR).

DISCUSSION AND CONCLUSION: Multi-VENC measurement of 4D PC-MRI sequence provided less noise levels compared to the single VENC measurement by improving the velocity-noise ratio. Although the accuracy of the flow field was improved by combining the flow velocity fields with various VENC parameters, the improvement of the flow at the post-stenosis was suppressed by high signal loss due to the phase dispersion. Therefore, signal loss at low VENC measurement should be minimized to optimize the improvement of the velocity field measurement using the multi-VENC PC-MRI.