TRAIN VELOCITY ENCODED PHASE CONTRAST MR IMAGING FOR PULSATILE VELOCITY ANALYSIS WITH IMPROVED TEMPORAL RESOLUTION AND VELOCITY-TO-NOISE RATIO

Pan-Ki Kim[1], Jeongmin Kwon[1], Hyeonjin Kim[1,2], Eun-Ah Park[1,2], and Whal Lee[1,2]
[1]Seoul National University, Seoul, Korea, [2]Seoul National Univ. Hospital, Seoul, Korea

Audience: clinical scientists and radiologists interested in the velocity measurement by phase-contrast MRI.

Purpose: Phase contrast magnetic resonance image (PCMRI) is regularly used to assess the interest velocity. To analysis using velocity curve (1-3), the time resolved PCMRI requires higher temporal resolution. However, as that method commonly employ the conventional data collection strategy (reference and velocity-encoded images in an interleaved manner), the maximum temporal resolution attainable for a given cardiac cycle is limited. Another limitation of these conventional velocity profiling methods is significant variation in the velocity-to-noise-ratio (VNR) over a cardiac cycle due to set the velocity encoding value (VENC) to above maximum velocity, in spite of an inverse relationship between VENC and VNR. In this study, the proposed PCMRI method is designed to concurrently improve the temporal-resolution and VNR. The goal is to describe the propose method and to demonstrate the feasibility compared with conventional PCMRI in phantom and healthy volunteers.

Methods: The proposed method (Train PCMRI) has composed with a velocity reference image at only first cardiac phase and then applied with a train of identical velocity encoding gradients for the rest of cardiac phase. The acquired phase images were slidingly subtracted between adjacent phase images by complex conjugate in each cardiac phase, and then the subtracted phase images were reconstructed to the velocity sensitized images by using cumulative summing manner, as illustrated in figure 1b. A homemade flow control system was used to compare between conventional and train method. Two health volunteers were measured for through-plane flow velocity of the abdominal aorta and femoral arteries on 3T scanner (Siemens, Trio). The imaging parameter were: repetition time(TR) = 5.1-5.5ms , echo time(TE) = 3.1-3.6ms, flip angle(FA)= 12 degree, number of average = 1, slice thickness (TH) = 6mm, 1 slice, readout bandwidth 650 Hz/pixel, rectangular field of view 300 x 150 mm2, acquisition matrix 256 x 128.

Results and Discussion: In phantom study, the mean velocities of conventional and train PCMRI have shown a strong correlation (R=1.00, $p<0.01$), and the velocity noise standard deviations in stationary gelatin region are linearly dependent as function of VENC, and both methods also strongly correlated (R=0.994, $p<0.01$). The conventional PCMRI with 2 view per segment(VPS) and train PCMRI with 4 VPS have same temporal resolution to 20ms, and the similarity of pulsatile flow curves is statistically highly correlated to 0.998 (cl, 0.995-0.999) in Lin's concordance-correlation coefficient(CCC). In in-vivo study, as shown in Figure 2, the CCC scored 0.98 ($p<0.001$) between the conventional PCMRI with 2 VPS and train PCMRI with 4 VPS. The VNR of train PCMRI (mean ± standard deviation: 19.62±2.72) is about twice as much as the conventional PCMRI (mean ± standard deviation: 10.97±4.82) according to VENC ($p<0.001$). The mean difference between two methods in Bland-Altman plot were 1.078 cm/s (95% CI for the means = -10.03; 12.05) and 0.413 ml (95% CI for the means = -2.81; 3.64) for peak velocities and flow, respectively.

Conclusions: The proposed train PCMRI method was concurrently provided the twofold temporal resolution and the increasable VNR using lower VENC compare with conventional PCMRI. And it can also use to reduce the total scan time by increasing VPS while maintaining the temporal resolution of the conventional PCMRI.

References: 1.Mousseaux E, et al. Radiology. 1999 Sep;212(3):896-902. 2.Elsankari S, et al. Journal of cerebral blood flow and metabolism. 2013 Sep;33(9):1314-21. 3.Mohajer K, et al. JMRI. 2006 Mar;23(3):355-60.

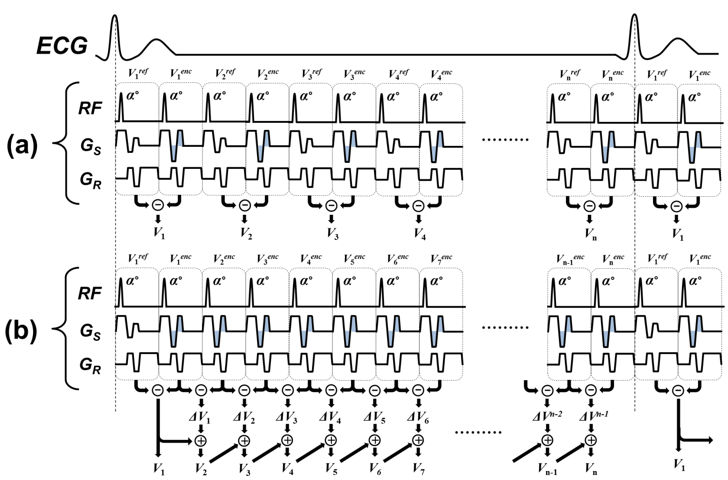

Figure 1. The ECG synchronized PCMRI sequence diagram is shown. The conventional PCMRI diagram is composed of the pair of velocity reference and encoding image (slash region) (a), and the proposed train velocity encoded PCMRI is composed of a velocity reference image and train of identical velocity encoded images over cardiac phase (b). These diagrams were drawn exaggeratedly without phase encoding. All gradients include velocity compensation in all three directions.

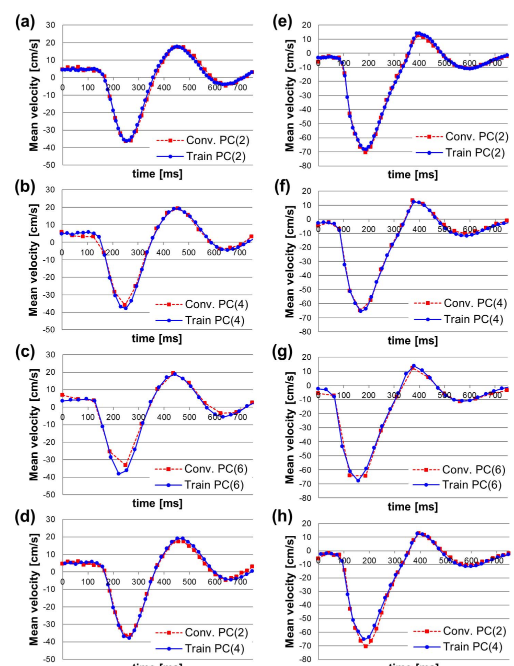

Figure 2. Mean velocity curves with various VPS in abdominal aorta (left column) and femoral artery (right column). These curves were acquired using conventional PCMRI at 160cm/s of VENC (square marked dash line) and train PCMRI at 80cm/s of VENC (circle marked solid line), with three times repeat. (a) and (e), The temporal resolutions of conventional and train PCMRI were 20ms and 10ms at 2 of VPS, respectively. (b) and (f), the both temporal resolutions at 4 of VPS were 40ms and 20ms. (c) and (g), the both temporal resolutions at 6 of VPS were 60ms and 30ms. (d) and (h), mean velocity curves of conventional PCMRI with 2 VPS and train PCMRI with 4 VPS, these have same temporal resolution.