

Inline Magnitude of Velocity Calculation for Phase Contrast MRA Improves Cardiac Valvular Assessment

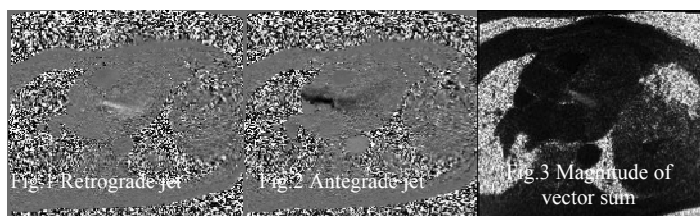
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Introduction: Phase-contrast MRI (PC-MRI) is a well established technique with a variety of applications in quantifying cardiovascular function and hemodynamics. There are however potential sources for error in PC-MRI when used in assessment of cardiac valvular disease. Apart from inappropriate selection of peak velocity encoding value (VENC), failure to orient slice position orthogonal to a post stenotic jet may lead to erroneous underestimation in peak flow velocity. Even with slice selection orientated parallel to perceived flow direction respiratory or cardiac motion during data acquisition may result in potential error in calculating peak velocity in the vessel of interest with PC-MRI¹. We propose inline computation of magnitude of peak velocity independent of direction to eliminate the reliance on slice orientation and facilitate evaluation of irregular flow patterns. We demonstrate the efficacy of this approach to in patients requiring cardiac valvular assessment.

Materials and Methods: The technique employs a phase contrast sequence with three flow encoding directions and one flow compensated reference. Phase difference images between each flow encoded and the flow compensated images were quantified for directional velocity. The root sum square of the 3D encoded data is computed inline and displayed in a magnitude of velocity (MagVelocity) data set for each patient. Thirteen patients (1 female, 12 males, avg. age 52.8), referred for cardiac valvular assessment underwent PC-MRI utilizing two in-plane and one through-plane flow encoding directions and inline computation of velocity magnitude on a clinical 1.5 T MRI scanner (Avanto, Siemens Healthcare, Erlangen, Germany). Evaluation of standard through-plane and direction-independent magnitude of velocity maps were performed by 2 blinded radiologists with a third radiologist screening all studies for diagnostic quality with regards to potential sources for miscalculation in peak flow velocity (improper VENC setting, inadequate temporal or spatial resolution). Of note, failure to orient the velocity-encoded 2D slice perpendicular to the jet did not preclude evaluation. All enrolled patients had a transthoracic echocardiogram performed within the last six months as the reference standard for velocity quantification. Peak velocity flow maps were generated with standard commercial software (Argus, Leonardo Workstation, Siemens Healthcare) after radiologist-defined regions of interest were mapped around the vessel lumen. ANOVA (analysis of variance) assessment using an F test to compare the means of the groups was performed prior to paired *t*-test statistical analysis of peak flow velocities for both standard through-plane and inline direction-independent phase contrast techniques.

Results: With correct slice orientation, standard through-plane and velocity magnitude both show retrograde and antegrade flow (Figs. 1, 2). However, one and two-tailed paired *t*-tests confirm that the inline directionally independent magnitude of velocity sum of squares technique has a significantly lower error in estimating aortic peak flow velocity than standard unidirectional PC-MRI using echocardiography as the reference standard.



Flow velocity curves at identical slice positions

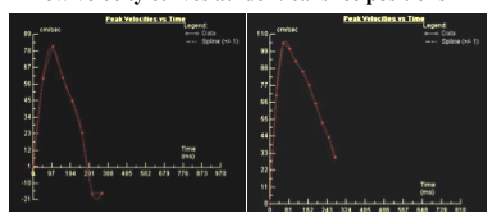
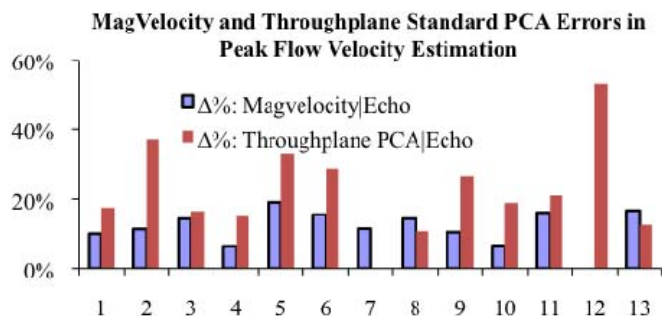


Fig.4 Through-Plane velocity 80cm/sec

Fig.5 MagVelocity Peak velocity 105cm/sec



Failure to orient slice position orthogonal to flow direction. Healthy subject with peak aortic flow velocity of 120 cm/sec with through plane (Fig.4) and MagVelocity (Fig.5).

Bar chart: displaying % variations from estimated Aortic valve peak velocity for MagVelocity and Through plane PCMR. Subjects 7 & 12 display no variation as MR estimated peak velocity agrees with echo peak velocity estimation.

When comparing standard Inplane and MagVelocity peak velocity estimations to reference standard, echocardiography, the mean error for MagVelocity is 11.7% (SD 5%) vs. 22.4 % for Through plane phase contrast MRI (SD 14%) supporting our initial hypothesis that extracting the magnitude of peak velocity independent of its direction reduces error in peak velocity determination.

Conclusion: Inline calculation velocity magnitude shows early promise to reducing potential error in calculation of peak flow velocity. Relative to standard through-plane PC-MRI, magnitude of velocity more closely approximates the reference standard of echocardiography for patients referred for cardiac valvular assessment. Ongoing clinical validation is aimed at identifying particular subsets of cardiac valvular disease in which the technique may demonstrate further improved accuracy.

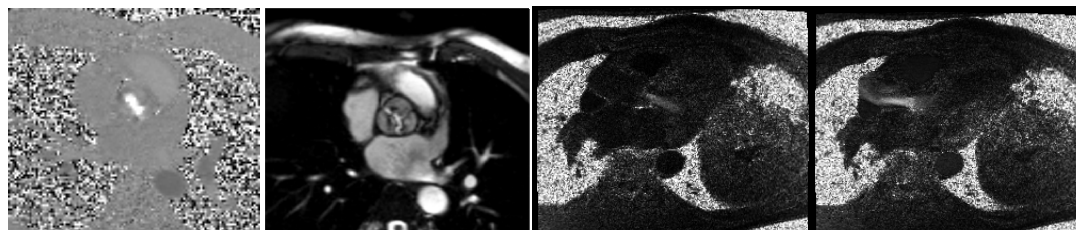


Fig.6 PCA in patient with bicuspid AV and stenosis

Fig.7 BSSFP (TrueFISP) image

Fig.8 MagVelocity demonstrating retrograde jet

Fig.9 MagVelocity demonstrating antegrade jet

References: 1.Srichai M, Lim R, Wong S, Lee V.S. Cardiovascular Applications of Phase-Contrast MRI. AJR 2009; 192:662-675