Coronary Blood Flow Measurement at 3.0T using Navigator-Echo Gated Phase Velocity Mapping

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Introduction: Measuring blood flow in the major coronary arteries has clinical significance for assessing coronary perfusion reserve or quantitatively comparing regions with poor and normal perfusion. However, even though phase-contrast imaging is a well-established technique for directly measuring fluid velocity in vivo, heart motion and minute size of the coronary arteries has limited its routine use. To address the latter issue, there is relevance to apply the technique at high field strengths, such as 3T, in order to garner greater in-plane resolution while maintaining high signal-to-noise ratio (SNR). Greater SNR has the added potential benefit of reducing background phase correction, especially for relatively low flow sampling, as is the case for coronary flow imaging. We believe that coronary flow imaging is one particular application well-suite for 3T cardiac imaging.

Purpose: To test the feasibility and to measure coronary blood flow velocity at 3.0T using navigator-echo gated cine phase velocity mapping (PVM).

Methods: Coronary blood flow was measured in 12 coronary vessels (6 RCA, 6 LAD) in six individuals on a Philips Intera 3.0T equipped with a 6-element cardiac phased array coil. To plan the flow measurements, an axial stack of 35-40 slices was first acquired over the heart using a prospectively, navigator-echo gated 3D coronary MRA sequence (segmented FLASH sequence, 270mm^2 FOV, 256matrix, TR/TE/flip = 3.8/1.9/20, 2mm slice thickness, 15-25 lines/segment centrically acquired, spectral fat saturation, T2-prep, SENSE reduction factor = 2). Acquisition was delayed to mid to late diastole, depending on quiescent period noted on transverse cine slice (50 phases acquired). Total imaging time for the axial MRA stack was approximately 2-3minutes free breathing. From the axial stack, a 3-point-plan scan was oriented by selecting a point at the coronary ostium and points in the mid and distal regions of either the left anterior descending or the right coronary artery. The 3D MRA sequence was repeated along this plane, with a reduction to 12 slices. Once the target artery was localized in-plane, a navigator-echo gated, PVM scan was positioned perpendicular to the coronary artery at a location of 4cm from the coronary ostia. The sequence was a segmented FLASH sequence (3 lines/segment), with flow encoded and non-encoded images separated by the heartbeat to allow more acquired phases. Other imaging parameters were: 256mm^2 FOV, 4mm slice thickness, 256 matrix, TR/TE/flip = 7.0/3.5/15, and the through-plane velocity encoded value was set to 30cm/s. This imaging sequence acquired 11-19 cardiac phases depending on the heart rate. Velocity measurements were evaluated using the FLOW software package (Medis, Lieden, The Netherlands). Regions-of-interest were drawn individually for each vessel cross-section using the magnitude phase-contrast images and then copied to the velocity encoded images. Both the average peak velocity and flow rate were measured in all arteries, and assessed in terms of inter-subject variance and known coronary flow rates.

Results: Clear images of coronary arteries were obtained in all volunteers, as shown in one volunteer (Figure 1). Coronary velocity was unmeasurable in 10/192 total phases (5.2%) due either to motion artifact or the vessel's proximity to the ventricular blood pool. An example cross-sectional RCA flow image is shown in Figure 2, along with a sample velocity curve. Average peak velocity over all subjects was 11.9±6.4cm/s in the right coronary arteries and 13.4±7.1cm/s in the left anterior descending coronary arteries. Average flow rate was 36.8±25.4ml/min in the right coronary arteries and 23.8±7.5ml/min in the left anterior descending coronary arteries. These measurements are within known values for coronary blood flow.

Conclusion: We have shown that navigator-echo gated phase velocity mapping of coronary flow is feasible at 3.0T. Further study will be done to compare signal-to-noise ratio, velocity-to-noise ratio, and accuracy to 1.5T studies.

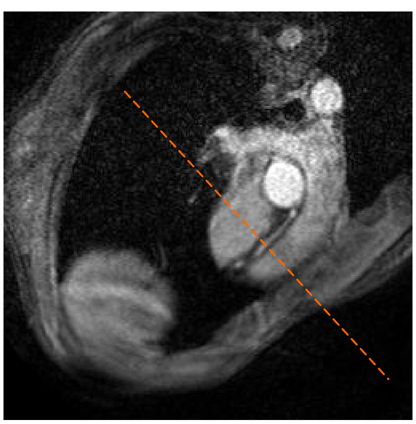

Figure 1. 3-point-plan image of a right coronary artery is shown with the slice plane used for a subsequent PVM scan.

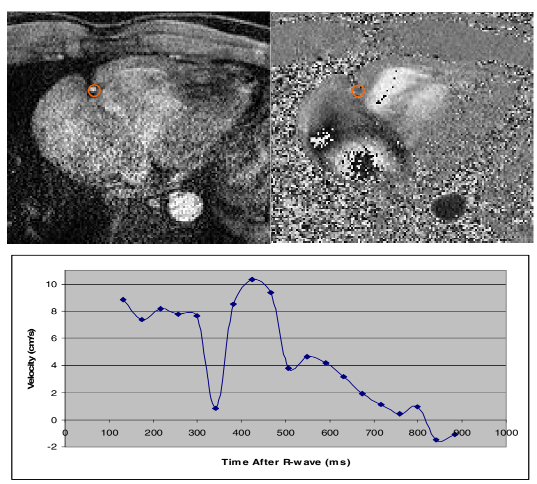

Figure 2. Cross-sectional modulus and phase images from an RCA PVM scan with the resulting velocity curve.