Measurement of Coronary Flow and Flow Reserve Using Phase-Contrast Magnetic Resonance Imaging

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Coronary flow reserve (CFR), defined as the ratio of hyperemic to resting coronary volume-flow rates (VFR), can be used to assess the severity of coronary artery disease. MR phase-contrast has the potential to non-invasively measure VFR if factors that introduce inaccuracies in coronary VFR measurements are corrected for.

For small vessels, phase-difference (PD) VFR measurements suffer from partial-volume errors. A complex-difference flow (CDF) method that is less sensitive to these errors is described and shown in both simulations and phantoms to measure VFRs more accurately than PD.

Through-plane myocardial motion can introduce errors in the measured coronary velocities. A through-plane motion correction scheme that can be applied to the PD and CDF techniques is described and validated in simulation and phantoms. Unvalidated PD and CDF measurements of coronary artery flow waveforms in a human volunteer are presented to illustrate the magnitude of the proposed through-plane motion effects in vivo.

Segmented k-space techniques can be used to eliminate the effects of respiratory motion by reducing the duration of a cardiac-gated acquisition to a breath-holding. A theoretical analysis of the temporal frequency response of segmented k-space phase-contrast (SPC) is developed. Increased segment duration results in low-pass filtering of the temporal flow waveform. This analysis was experimentally verified in phantoms and demonstrated in a volunteer.

A study was conducted to demonstrate the feasibility of performing MR coronary VFR and CFR measurements in normal volunteers. Data was acquired and processed using the previously mentioned techniques. The results showed that VFR and CFR measurements using the described MR techniques are feasible and are similar to those reported in the literature for healthy volunteers.

A new method that addresses some of the shortcomings of SPC for measuring pulsatile flow is described (PC-VARKS). In this method, acquisition time is reduced by varying the rate at which views are sampled. Views closer to the k-space origin are sampled more often and views further from the origin sampled less often. Phantom and in vivo experiments show PC-VARKS to have better temporal frequency response than breath-hold SPC for the same total acquisition time over a wide range of vessel sizes.