Quantitative Real-Time Color Flow MR: A Comparison With Doppler Echocardiography

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Introduction:

Intracardiac velocities are sensitive indicators of disease in many cardiac abnormalities including the degree of valvular stenosis, regurgitation, and myocardial systolic and diastolic function. However, the determination of abnormal blood flow velocities in the heart requires accurate quantitation of blood flow velocity and timing. This clinically relevant information is also frequently gathered as dynamic response to manipulation of the hemodynamic state such as changes in the preload or afterload. Prior work in the area of real-time color flow [1] and flow quantitation has been shown [2,3,4]. This work demonstrates that the flow quantitation can be integrated into a realtime interactive environment suitable for routine clinical evaluation. We have developed a blood-velocity flow mapping sequence that enables the measurement of velocity and volumetric flow information in real-time. Real-time blood flow velocity information, similar to Doppler echocardiography, and quantitative volumetric flow measurements are demonstrated.

Methods:

The real-time color flow application was implemented as part of the flexible architecture proposed in [5,6] on a GE 1.5 Signa TwinSpeed system (GE Healthcare, Waukesha, WI) with a high performance gradient system (maximum gradient strength of 40mT/m and maximum slew rate of 150mT/m/msec). Three modes were available in our real time color flow system: real time localizer, real time shim, and real time color flow. The current study utilized a spiral-based real-time flow sequence [1], but the implementation supports other trajectories as well. The imaging parameters common to all acquisition modes include: 480us sinc excitation pulse, 5mm slice thickness, 4ms readout, and 30° flip angle. The minimum TE was 2.2ms for a maximum velocity encoding (v_{enc}) of 2.5m/sec and minimum TR was approximately 11ms. The spiral trajectory for the real-time localizer used 4 interleaves and the color flow module used a 2 interleave spiral trajectory. This resulted in a temporal resolution of 45ms for both real-time localizers and real-time color flow. Contextual information including slice location, prescan parameters, and shim values is automatically shared between the real time localization and color flow modes. The user was allowed to prescribe a region of interest (ROI) on the color-overlaid image. The mean velocity from the ROI was plotted in real-time in a separate window and a plot of real-time cardiac output (CO) was also displayed. CO was calculated by time averaging the last 6 seconds of the flow data. The v_{enc} values could be changed dynamically, allowing the user to optimize the value for a particular region.

Following informed consent, subjects were imaged with real-time MR color flow followed by Doppler echocardiography. Care was taken to scan approximately the same plane and to localize the ROI at approximately the same location for both imaging modalaties. The shape of the waveforms was compared. In addition, MR real-time CO data was acquired while the volunteer performed the Valsalva maneuver. Real time CO was not available on the echo machine.

Results:

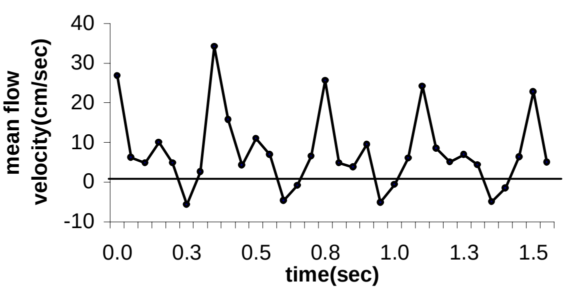
Figure 1 shows the velocity waveform from (a) the MR color flow system and (b) the echo Doppler system in the same volunteer from a plane containing the mitral valve. The Doppler waveforms show the spectral content of velocities vs. time while the MR waveforms show the mean velocity at each time point. Waveform shapes were similar. Figure 2 shows the real-time cardiac output data for a 6-second window during which the volunteer was asked to perform Valsalva maneuver. The CO drops, as expected, when the patients performed the maneuver and returned to normal after breathing resumed. The rest state real-time CO was 95-100cc/sec, as expected, for a healthy volunteer.

Discussion and Conclusion:

Real-time localized velocity measurement tools enable the assessment of multiple physiologic conditions in the course of a typical cardiac magnetic resonance examination. We have demonstrated the feasibility of quantitatively measuring valvular blood flow patterns as well as volumetric blood flow in an integrated real-time cardiac imaging environment. Further clinical studies are ongoing to establish the clinical utility of this technique.

References:

1. Nayak, K et al. MRM 2000, 251-258.
2. Hu BS, et al. MRM 1993, 393-398.
3. Hardy CJ, et al. MRM 1994, 513-520.
4. Pat GT,et al. MRM1998, 603-613.
5. Santos J, et al. ISMRM 2002, 738.
6. Shankaranarayanan, A et al. SCMR 2003, 294-296.



(a)

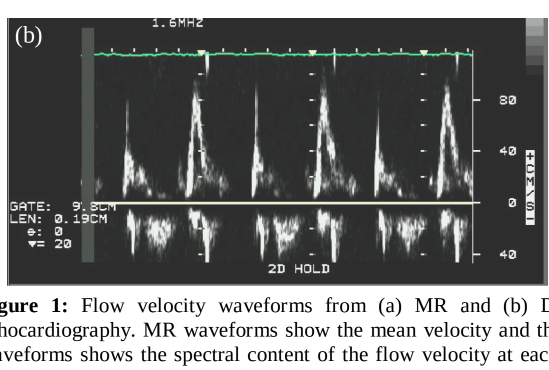


Figure 1: Flow velocity waveforms from (a) MR and (b) Doppler echocardiography. MR waveforms show the mean velocity and the echo waveforms shows the spectral content of the flow velocity at each point in time. Note that the shape of the waveforms appear similar.

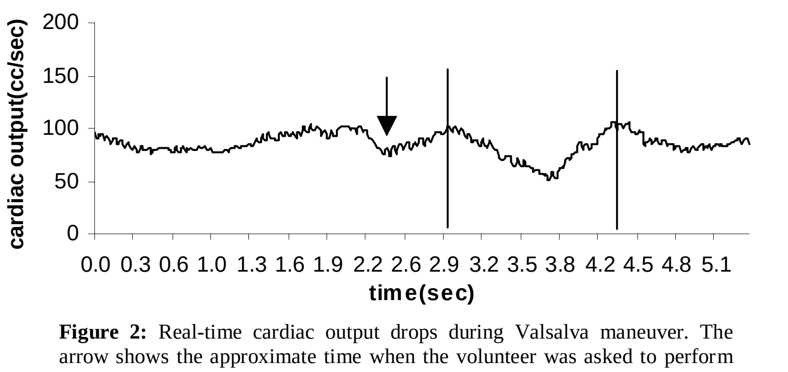


Figure 2: Real-time cardiac output drops during Valsalva maneuver. The arrow shows the approximate time when the volunteer was asked to perform the maneuver. The vertical lines indicate the time segment of dip in cardiac output related to the Valsalva maneuver.