Real-Time and Cardiac Gated CINE MR Doppler

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Introduction: The examination of valvular heart disease includes the assessment of valvular morphology, cardiac output, intra cardiac pressures, ventricular volume and volume regurgitations. Magnetic resonance imaging (MRI) is potentially the most appropriate technique for addressing all of these areas in a single examination. We have previously implemented an MRI subsystem that seamlessly integrates most of the capabilities needed for a comprehensive valve evaluation [1]. However, real-time Doppler [1-5] suffers from limited temporal and spatial resolution.
In this work, we have expanded this system to include a cardiac gated CINE MR Doppler sequence to improve the resolution and velocity range of our previously demonstrated Real-Time MR Doppler sequence while retaining adequate real-time behavior for monitoring physiological changes (eg. respiration).

Methods: We have developed a cardiac gated CINE MR Doppler sequence that can be immediately prescribed from a real-time MR Doppler acquisition and real-time color flow in cases were higher velocity spectra resolution or dynamic range are required. The MR Doppler sequence consists of a cylindrical selective excitation followed by and interleaved bowtie Fourier velocity encoding readout gradient. For real-time velocity quantification, a few interleaves of relatively long duration are designed to achieve good intra cardiac temporal resolution while maintaining a tolerable level of motion artifacts. Intra cardiac temporal accuracy and spatio-temporal resolution can be improved by doing a CINE cardiac gated acquisition of an increased number of short duration interleaves. Because only a few heartbeats are required, the acquisition can run continuously in a pseudo real-time mode using a sliding window reconstruction algorithm (Fig. 1). A new multiphase reconstruction is obtained with every heart beat by updating the previously acquired data. This allows studying dynamic changes in blood flow with a temporal resolution corresponding to the number of heartbeats that form a complete acquisition. For both the real-time and the cardiac gated sequences, the system can change waveforms to adjust for the appropriate maximum velocity. In the example, an aortic valve from a healthy volunteer was evaluated. A maximum velocity of +- 200 cm/s was selected (from a range between 100 and 600 cm/s). This resulted in the following parameters for the real-time sequence: 3 interleaves of 6.8 ms readout length and 20 ms TR, 34.8 cm/s velocity resolution, 33 cm Z FOV and 5 mm Z spatial resolution. For the cardiac gated sequence: 8 interleaves of 7.5 ms readout length and 22 ms TR, 12.2 cm/s velocity resolution, 35 cm Z FOV and 6mm Z spatial resolution.

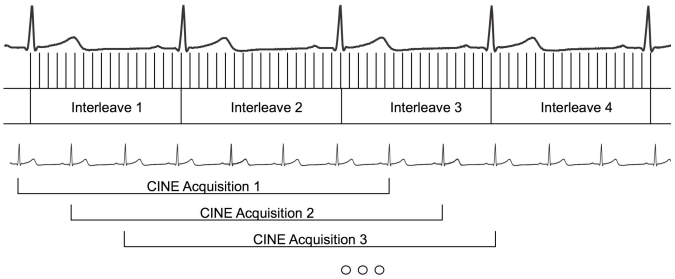

Figure 1: Sequence diagram. CINE temporal ordering is used to reconstruct a multiphase loop out of 8 heartbeats. Consecutive heartbeats are used to generate new CINE acquisitions for continuous evaluation.

Results: The system was evaluated with a normal volunteer. Starting with real-time anatomical images, the aortic valve was localized. Color-flow was then enabled to assess regurgitation through the valve and to further localize the FVE measurement. Real-time MR Doppler was enabled to measure the velocity spectra distribution. Cardiac gated CINE MR Doppler was then used to obtain a higher resolution velocity waveform.
The figure on the bottom left shows the resulting spectra acquired in real-time. The top left image demonstrates the corresponding cardiac gated higher resolution acquisition. The top right image shows a single frame of the position vs. velocity representation where it is possible to observe the velocity gradient through the valve. While this technique suffers from the need for sinus rhythm, the improved accuracy should be helpful for a large number of patients with regular rhythm.

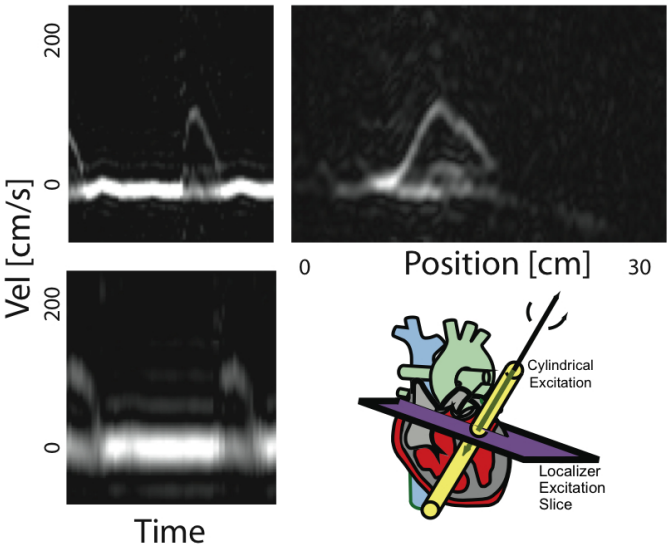

Figure 2: Velocity spectra through the aortic valve measured with real-time FVE (bottom left) and cardiac gated FVE (top).

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