Comprehensive Valve Evaluation System

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Introduction: Valvular heart disease affects approximately 10% of patients with heart disease in the United States. Over the past 20 years, noninvasive valvular diagnosis has undergone a revolution due to advances in cardiac ultrasound. However, ultrasound has inherent limitations with respect to tissue characterization, spatial resolution, and the need for acoustic windows. Particularly challenging are the quantitation of valvular stenosis, quantitation of valvular regurgitation, and the accurate evaluation of valvular morphology.
The examination of valvular heart disease includes the assessment of valvular morphology, cardiac output, intracardiac 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 designed and MRI subsystem that seamlessly integrates most of the capabilities needed for a comprehensive valve evaluation.

Methods: We have previously developed a real-time interactive system [1] that allows for rapid switching (in one TR) and interleaving completely different pulse sequences. Under this platform we implemented a high frame rate continuous real-time acquisition (9–12 fps) using SSFP and GRE contrast for evaluation of aperiodic valve motion. Valvular morphology is imaged using a high resolution (0.7 mm in plane) double inversion cardiac gated black blood technique with 16 spiral interleaves. As localization is critical, the real-time acquisition is used to precisely prescribe the view of interest and within one TR the system can start acquiring the high-resolution images. To evaluate valvular regurgitation we have implemented a color flow sequence [2]. This is a real-time phase contrast acquisition that can acquire a full frame at a rate of 6fps. The images are then reconstructed at 20 fps.
Intracardiac flow velocities are evaluated using a real-time velocity spectra or MR Doppler sequence [3-5] where the MR signal is restricted to a 2D cylinder. The cylinder is then resolved in both velocity and along its length using an oscillating readout gradient. A measurement can be obtained every 25 ms and different range of velocities can be resolved depending on the readout trajectory.
One of the aims in the design of this system is to be comparable with cardiac ultrasound. The typical workflow is to first locate the anatomy with the real-time sequence (Fig. 1). Then, color flow is activated to precisely scout for the areas were flow is to be measured. Finally, MR Doppler can be enabled simultaneously with the color flow images, so flow information can be used to prescribe the location of the beam excitation. Color-flow is then stopped for better velocity spectra temporal resolution.

Results and Discussion: Three patients and 4 volunteers were evaluated with this system. For all the cases, anatomical information was obtained in real-time. Then color flow and MR Doppler were used to obtain flow information. The figure shows a color flow image in the aortic valve plane with through-plane flow encoding. The arrow shows the regurgitation through the valve. Using the MR Doppler technique, the figure shows the waveforms from the mitral (top) and aortic valve (bottom) of a patient with moderate stenosis.
These preliminary studies have shown that this system is capable of rapidly and accurately identifying clinically significant valve regurgitation and stenosis.

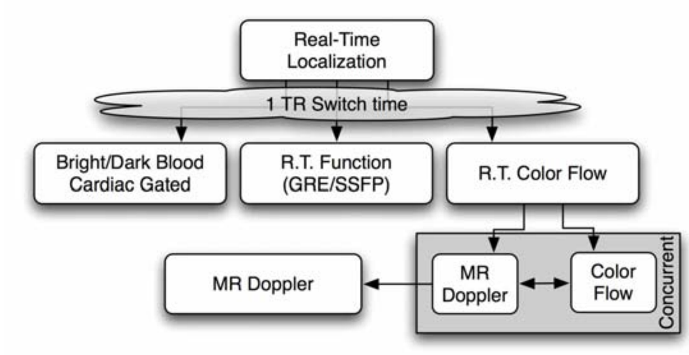

Figure 1: Workflow diagram.

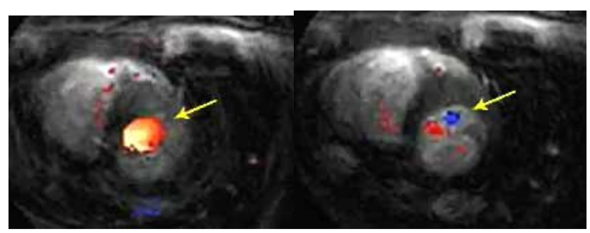

Figure 1: The real-time color-flow images show regurgitation through the aortic valve (two frames of the time sequence are shown). LV outflow velocity is seen on the left panel. Moderate regurgitant aortic flow is mapped as the blue jet in the LV outflow tract (Right Panel).

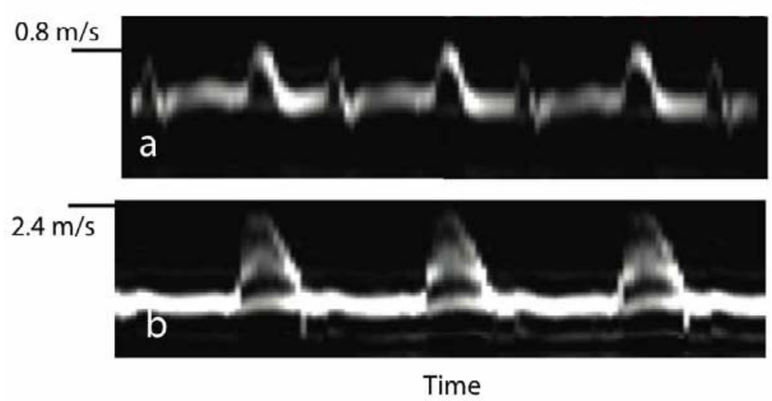

Figure: The real-time MR Doppler waveforms demonstrates the typical E and A waves through the mitral (top) valve and elevated aortic valve flow (bottom) on a patient with moderate stenosis.

References

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