**Real-Time Color overlay Cardiac Phase Contrast Spiral imaging at 3 Tesla**

Chia-Ying Liu, Padmini Varadarajan*, Gerald M. Pohost*, Krishna S. Nayak
Electrical Engineering, University of Southern California, Los Angeles, CA, USA
*Cardiovascular Medicine, University of Southern California, Los Angeles, CA, USA

**Introduction:**
The ability of MRI to quantify blood flow with high spatial and temporal resolution has made it a method of choice for accurate blood flow mapping in-vivo. The challenges comprise the development of techniques to accurately assess blood flow through heart valves by incorporating appropriate respiratory and cardiac motion compensation schemes as well as very fast measurement techniques to assess transient changes of blood flow such as ischemia-mediated flow responses. Nayak et al. have performed the real-time color flow MRI [1] in 1.5T systems. In this work we develop a fast spiral phase contrast pulse sequence and real-time reconstruction to compute both velocity and density maps in 3T systems. The spiral was chosen because of its insensitivity to motion and flow, and time efficiency. No breath holding or gating is required. We design two spiral acquisitions including uniform (uds) and variable (vds) density trajectories with different spatial resolutions. Image quality and performance were compared qualitatively by independent observers.

**Purpose:**
To demonstrate and evaluate the usefulness of real-time spiral phase contrast sequences at 3 Tesla for imaging cardiac flow.

**Methods:**
We implemented the phase contrast sequence and image reconstruction algorithm based upon the MRI platform developed by Santos et al. [2]. The system uses an external workstation for real-time control of sequence parameters and real-time reconstruction, and is capable of imaging dynamic processes. The pulse sequence consisted of a water selective spectral-spatial excitation [3], bipolar gradient, spiral readout, and gradient spoiler. The operator can interactively adjust the scan plane acquisition parameters including the imaging flip angle, field of view, and slice thickness. The scan plan prescription can be conveniently defined by deposition points and have the ability to jump at any time to the standard axial, coronal, and sagittal planes. Flow encoding can be dynamically changed in three different directions. Symmetric encoding of two bipolar waveforms with equal and opposite first moments was used to reconstruct the phase and magnitude images. The following parameters were used for all studies: TR=12.5ms, TE=6.12ms, FOV=24cm, Flip Angle=20degree, velocity encoding of 100cm/sec, and six interleaves. The temporal resolution of 150ms and nominal spatial resolution of 2.3mm and 1.5mm can be achieved for uds and vds respectively. Experiments were performed on a GE Signa Excite HD 3T scanner equipped with gradients supporting 40 mT/m amplitude and 150 T/m/s slew rate, and fast receiver. An eight-channel cardiac phase array coil was used in human subject studies, with only three coil elements used for image reconstruction.

**Results and Discussion:**
A feasibility study to evaluate the real-time performance and image quality was conducted with five healthy subjects. Each volunteer was scanned with the primary interest of visualization of cardiac flow into and out of the left ventricle. Axial, four chamber, three chamber, and two chamber views
were scanned and saved. Representative real-time images of the left ventricle aortic outflow both with and without color overlay are shown in Figure 1. Based on reviews from two independent observers trained in cardiac MR, the vds images were of higher image quality compared to uds.

The temporal resolution can be improved by reducing the spatial resolution. For example, four interleaves can be used instead of six in the spiral design. The temporal resolution of 100 ms can be achieved with 3.0 mm of spatial resolution.

Conclusions:
This study provides the first demonstration of real-time color flow MRI at 3 Tesla, based on spiral phase contrast imaging. This technique provides rapid visualization of cardiac flow. Further validation in patient cohorts with valvular stenosis and regurgitation are underway. The use of the interactive real-time system offers substantial reductions in scan time and complexity (free-breathing and no gating) for cardiovascular applications.

References: