VARIABLE-DENSITY SPIRAL IMAGING FOR REAL-TIME COLOR FLOW CARDIAC MRI AT 3T

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Introduction The ability of MRI to quantify blood flow with high spatial and temporal resolution has made it a promising technique for accurate blood flow mapping in-vivo. Nayak et al. have performed the real-time color flow MRI [1] in 1.5T systems. In this work real-time color flow MRI is developed on a 3T system based on a spiral phase contrast pulse sequence and real-time reconstruction. Two variable density spiral (VDS) acquisitions with different temporal and spatial resolutions were used and compared with conventional uniform density spirals (UDS).

Methods Flexible spiral phase contrast imaging was implemented within a real-time MRI platform developed by Santos et al. [2]. The platform enables interactive slice prescription and dynamic continuous image acquisition. As data is acquired, it is transferred to an external computer for gridding, reconstruction of phase images, and color image display. The pulse sequence consisted of a 3.6 ms of spectral-spatial excitation, bipolar gradient, spiral readout, and gradient spoiler. Variable density spirals were implemented [3] to increase temporal or spatial resolution (see Table 1) compared to uniform density. UDS-A represents a conventional UDS with 2.3 mm spatial resolution and 150ms temporal resolution. To keep the same temporal resolution as UDS-A, VDS-B was designed to have the same readout length but extended coverage in *k*-space to achieve higher spatial resolution (1.5 mm). VDS-C was designed to achieve the same spatial resolution with reduced readout length and number of interleaves to improve temporal resolution (40% compared with UDS-A). Table 1 and Figure 1 compare the three different *k*-space trajectories. Experiments were performed on a GE Signa Excite HD 3T scanner. No breath holding or gating was required in any studies. An eight-channel cardiac coil was used but only three elements were reconstructed for phase contrast, phased array reconstruction [4]. Sliding window reconstruction was used to achieve a highest possible frame rate of 40 frames/sec.

Results and Discussion The objective of the experiments was to evaluate the cardiac flow imaging capabilities of the VDS acquisitions. Figure 2 illustrates left ventricular outflow track (LVOT) in a three-chamber view from a normal volunteer. The velocity encoding (VENC) was set to 100 cm/s, which was lower than the maximum flow velocity of this volunteer (indicated by the phase aliasing of the color display in LVOT). All spirals have comparable image quality. Fig.2 (bottom) plots the velocity profiles along the LVOT (white dash line on UDS-A color image) on four consecutive images. Phase 1 depicts the maximum systolic outflow. Velocity aliasing is clearly visible in the images but was unwrapped to produce the velocity profiles. Phase 2 (blue dashed line) has the same high velocity. Phase 3 and 4 are 50 and 75 ms towards diastole. The comparable image quality and velocity profiles of UDS-A, VDS-B and VDS-C demonstrate the flexibility of variable density spirals for use in real-time color flow MRI.

Conclusion This study provides the first demonstration of real-time color flow MRI at 3T using spiral phase contrast. This technique provides rapid visualization of cardiac flow with the SNR benefits of 3T systems. Further validation in patient cohorts with valvular disease are planned. The use of the variable density spiral design offers substantial flexibility in increasing the spatial or temporal resolution for cardiovascular applications.

References [1] Nayak KS, et. al. MRM 2000;43:21-258. [2] Santos JM, et.al. 26th Annual Int. Conference IEEE EMBS, 1048(2004). [3] Hargreaves B, www-mrsrl.standford.edu/~brian/vdspiral [4] Bernstein MA, et al. MRM 1994;32:330-334.

Table 1	UDS-A	VDS-B	VDS-C
FOV (cm)	20	20 -- 4	20 -- 4
Spatial resol (mm)	2.3	1.5	2.3
Interleaves	6	6	4
Gradient duration (ms)	6.312	6.368	5.048
Grid points	88	134	88
Temporal resol (ms)	75x2	75.3x2	45x2

Figure 1. k-space trajectories in Table 1.

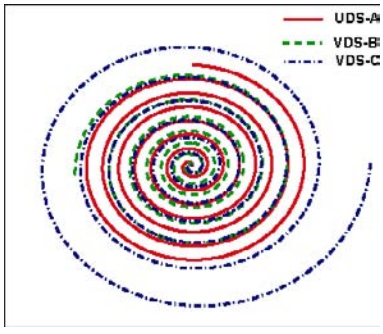

Figure 2. Three-chamber color-flow images in a normal volunteer. (Top) All spirals have comparable image quality with color display. (Bottom) The velocity profiles along the LVOT (white dashed line) in four consecutive frames. Phase 1 contains maximum systolic outflow. Velocity aliasing is clearly visible. Phases 2 (blue), 3 (green) and 4 (black) are 25, 50, and 75 ms towards diastole.