Self-Navigated Phase Contrast MR

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Introduction: Measurement of flow in pulmonary blood vessels from MR requires compensation for respiratory motion. Breath holding is sufficient for short scan times, but fails when longer scan times are required. Examples of such scans include high spatial resolution imaging of small peripheral pulmonary vessels and high temporal resolution measurement of blood flow for pulse wave velocity calculation. Self-navigation is a technique that enables long scan times with free breathing and improves image quality by using image data to determine the position of the anatomy during data acquisition. This technique has previously been applied to SSFP imaging [1] and, in this abstract, is extended to retrospectively cardiac-gated phase contrast (cine PC) MR.

Methods: Self-navigated cine PC MR is a modification of the conventional cine PC MR sequence. At the beginning of each R-R interval, a 1D projection of the anatomy is acquired. This projection is the Fourier transform of a line through the centre of k-space (k_0) oriented in the primary direction of motion and represents the anatomic position of the R-R interval from which it was obtained. An initial k_0 line is used as a template to which subsequent k_0 lines are compared. If a k_0 line is poorly correlated with the template, the PC MR data for that R-R interval is discarded and reacquired in real time.

The self-navigated PC MR sequence was assessed in vitro on a 1.5 T MR system (Excite III, GE Healthcare) with a flow phantom. The phantom consisted of a servomotor driving water through a tube surrounded by air. In vivo blood flow was simulated with a cardiac rate of 57 bpm. The phantom was moved back and forth to simulate respiratory motion at 9 cycles per minute with a maximum displacement of 2 tube diameters. Self-navigated cine PC MR and conventional multi-averaged cine PC MR data were obtained with a moving and stationary phantom. Apart from number of averages, multi-averaged cine PC MR (2 averages) and self-navigated cine PC MR (1 average) were performed with the same parameters.

Results and Discussion: Respiratory self-navigation is similar to conventional navigator echoes [2], but has several advantages. Self-navigation provides a direct measure of motion rather than an indirect measure from the diaphragm. In addition, self-navigated cine PC MR continues imaging throughout the cardiac cycle rather than breaking to obtain a navigator echo, allowing more of the cardiac cycle to be imaged while also maintaining the steady state.

A multi-averaged PC MR image (Figure 1a) of the moving tubes shows blurring and ghosting artifact. These effects are absent in the self-navigated PC MR image (Figure 1b), which clearly shows the moving tubes in one position only. The Fourier transform of k_0 lines (Figure 1c) demonstrates the change in position of the tubes over time. The Fourier transform of k_0 lines associated with R-R intervals used in the self-navigated cine PC MR scan (Figure 1d) confirms that the tubes were in a consistent position during data acquisition. Measures of volume flow rate (VFR) (Figure 2) were dramatically improved using respiratory self-navigation. The self-navigated VFR closely matches the reference curve, while the multi-averaged VFR is both distorted and decreased in amplitude.

These results show that self-navigated cine PC MR is an improvement over multi-averaged cine PC MR in terms of image quality and flow measurement. This technique can be applied to pulmonary blood flow in vivo to compensate for respiratory motion by obtaining k_0 lines along the direction of respiratory motion. The motion of the heart poses a complication since it has a periodicity that is different than the respiratory cycle. Rather than using the k_0 line itself, a metric more suited to motion in the lungs may improve respiratory compensation in vivo.

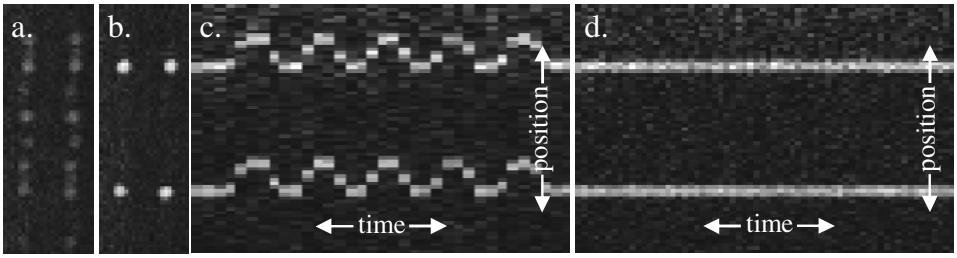

Figure 1: Single cardiac phase of cine data showing a cross-section of the moving tubes obtained with (a) multi-averaged cine PC MR and (b) self-navigated cine PC MR. (c) Fourier transform of k_0 lines from first 35 R-R intervals. Lines are arranged as columns side-by-side in the order they were obtained. (d) Fourier transform of all k_0 lines associated with R-R intervals used in (b).

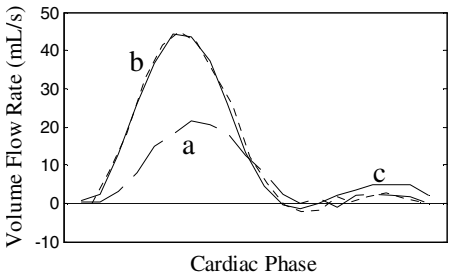

Figure 2: VFR in moving tubes from multi-averaged cine PC MR (dashed line, a) and self-navigated cine PC MR (dotted line, b) compared to multi-averaged cine PC MR (solid line, c) VFR from a non-moving tube. The same region of interest was selected from each set of PC MR data.

References: [1] Li J.M. *et al*., ISMRM (2005) p. 2234. [2] Wang Y. et al., MRM (1995) 33, p. 713-719.