Validation of DC Self-Navigation for Breath-hold Period Identification in Contrast-Enhanced 3D Radial Liver Perfusion Imaging

D. E. Horng[1,2], E. K. Brodsky[1,2], and S. B. Reeder[1,2]
[1]Radiology, University of Wisconsin-Madison, Madison, WI, United States, [2]Medical Physics, University of Wisconsin-Madison, Madison, WI, United States

Introduction: Quantitative perfusion imaging of liver tumors requires acquisitions that occur during alternating periods of breathing and breath-holding. Knowledge of the time range when the liver is not moving is necessary for perfusion modeling, typically a quantitative parametric map characterizing the blood flow to the liver. Although respiratory bellows are a simple external measure of breath-holding, their use complicates the scan procedure and is only an indirect measure of respiratory motion.

Larson et al. used "self-navigating" radial projections to identify breath holds for coronary artery MRA[1], and the use of the magnitude of the DC signal to detect motion has been described by Brau and Brittain[2] for self-navigation. In this work, we describe the use of DC phase and magnitude signal measured from 3D-radial contrast enhanced acquisitions to identify breath-holding periods for liver perfusion MRI.

Methods: After obtaining IRB approval and informed consent, 4 subjects were imaged using an undersampled 3D radial time-resolved acquisition, that was performed at 3.0T (MR750, GE Healthcare, Waukesha, WI)[3,4].

Digitized bellows waveforms were collected during the scan as a reference standard. Bellows data were sampled once every 10 TR (TR=2.7 ms), and DC magnitude and phase data were collected every TR since the center of k-space is sampled every TR with radial imaging.

A GUI was developed with Matlab (Mathworks, Natick, MA) to display the DC waveform (both magnitude and phase components), along with a low-resolution (64x64x64 voxels) image preview, and the bellows waveform. The image preview can display coronal, sagittal, and axial views, and provides an overview of the liver motion for the user.

The DC waveforms were filtered with a zero-phase filter, in order to prevent any undesired lag in the breath hold selections. The FIR (finite impulse response) filter has a real, even impulse response in order to make the phase zero. The filter cutoff was chosen subjectively to optimize the appearance of the DC waveforms.

Breath hold periods were selected three times for each scan, based on each of the magnitude, phase, and bellows waveforms. Each waveform-based selection was blinded to the other two waveforms. The image preview (Fig. 1) was not used in generating the data presented here, in order to provide a blinded evaluation of the tool. The selections based on magnitude, phase, and bellows were then correlated to show the accuracy of magnitude and phase selections, compared to bellows.

Results: Fig. 1 is a screenshot of our Matlab GUI. The light blue boxes are the breath hold periods based on all three waveforms. In this particular case, the blinded DC phase waveform misses the third breath hold period; however the DC magnitude waveform clearly shows the breath hold period. Figs. 2 and 3 display the correlations of the start/stop times of all selections from all scans.

Discussion and Conclusion: Although the DC breath hold selection method is very accurate for both DC magnitude and phase waveforms, occasionally a breath hold was missed entirely. Out of 13 breath holds in 4 scans, as determined by bellows waveform, the DC magnitude selection missed 1 breath hold, and the DC phase selection missed 3 breath holds; however, no breath hold was ever missed by both DC magnitude and DC phase. A more advanced filter may result in fewer missed breath holds. However, when the magnitude or phase selections were successful, they were very accurate (see r^2 values in figures: 0.994, 0.999, 0.993, and 0.997).

References: **1.** Larson AC, *et al.*, MRM 54(2):470-475. (2005) **2.** Brittain JH, *et al.*, MRM 55(2):263-270. (2006) **3.** Brodsky EK, *et al.*, MRM 56(2):247. (2006) **4.** Johnson KM, *et al.*, Proc. 22nd MRA Club:10.9 (2010)

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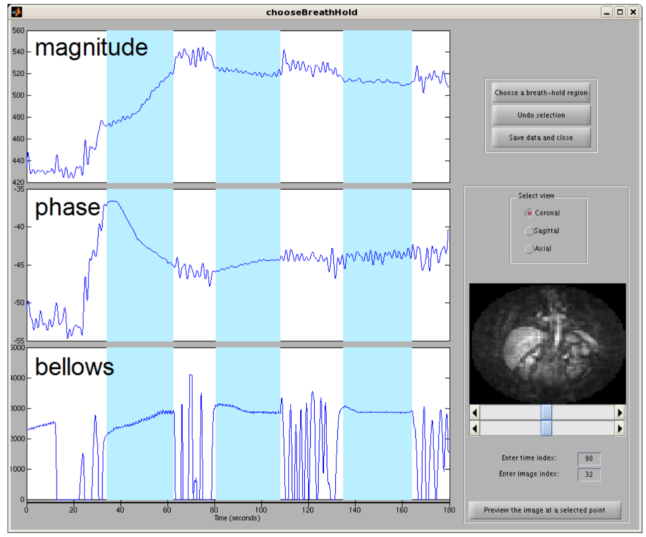

Fig. 1: Matlab analysis tool with magnitude (top), phase (middle), and bellows (bottom) waveforms. An image preview is shown on the right side, with a coronal view selected.

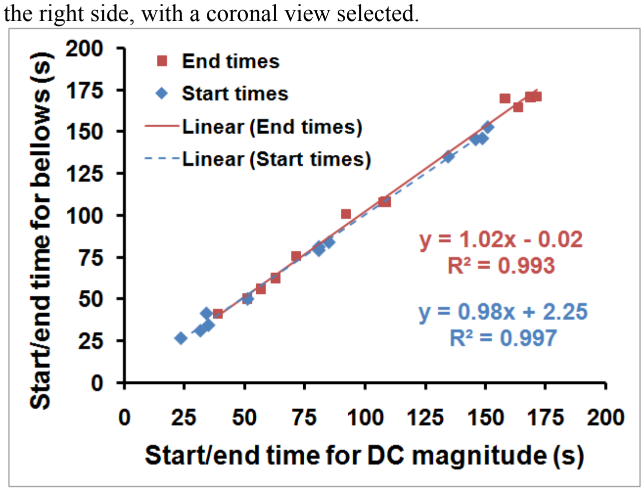

Figure 2: Excellent correlation is observed between the bellows start and end times and the DC magnitude start and end times.

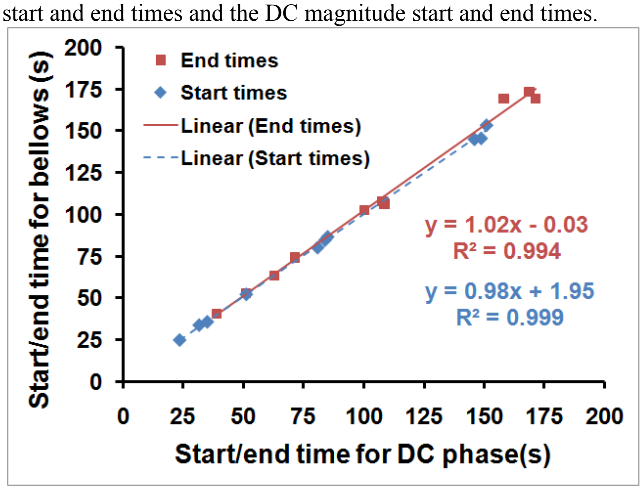

Figure 3: Excellent correlation is observed between the bellows start and end times and the DC phase start and end times.