Cine-Navigator Imaging: Self-Navigating Respiratory Motion Correction for Free-Breathing Cardiac Cine-MRI

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Introduction: In cardiovascular MRI, breathing motion will blur images, usually beyond diagnostic value. While breath-holding is the standard solution, this approach limits the information that can be acquired in a given study to a breath-hold duration. Furthermore, many patients have difficulty holding their breath, and pediatric patients cannot hold their breath at all or are anesthetized. Conventional navigator methods are not appropriate for respiratory motion correction for cine imaging experiments due to the time required to excite the navigator tissue, to acquire the information and then establish steady-state conditions for the primary imaging experiment. We will demonstrate a free-breathing cine imaging approach, *cine-navigator imaging*, to correct displacements due to breathing and provide breath-hold-like images.

Methods: A retro-gated steady-state free precession (SSFP) pulse sequence was used for all experiments. All MR measurements were performed with a Siemens Sonata 1.5T scanner (Siemens Medical Systems, Erlangen, Germany). The cine-navigator technique incorporates an interleaved segmented radial k-space trajectory to allow real-time images to be acquired throughout a conventional gated-segmented experiment, using the same k-space data for both purposes. In order to maintain the temporal resolution of the ultimate gated-segmented cine image series, each segment (i.e. each real-time image) is repeated over several heartbeats. Pulse sequence parameters:TR/TE = 3.2/1.6 ms, flip = 60^o, FOV = 36 cm, 32 views per real-time image (~100ms), 256 readout points, 128 to 256 projections. Free-breathing volunteers were imaged for 12-24 seconds. An intensity-based registration algorithm [1] was used to register the real-time images to reference images, for each cardiac phase, providing cardiac-motion-independent respiratory motion information. The reference images are real-time images acquired at end-expiration. Affine transformation parameters calculated from image registration were applied to the raw k-space data, which was then used to reconstruct conventional gated-segmented cine images, with motion correction.

Results: To quantify the ultimate image quality, the normalized sharpness (Shnorm) is defined as first-order derivative of the signal intensity over a profile drawn on the image, divided by the mean signal intensity in an ROI drawn on the blood in the left ventricle. Table 1 shows the mean and standard deviation of the maximum absolute Shnorm (max |Shnorm|) values for five profiles drawn on free-breathing (pre- and post-correction) and breath-hold cine-image series at three cardiac phases for the 9 volunteer studies acquired. Figure 1 shows normalized signal intensity profiles.

Conclusions: There is a significant improvement (***12-67%***) in max |Shnorm| values for the 9 volunteers in this preliminary study, regardless of breathing pattern, with the greatest improvement seen in the profiles in the direction of respiratory blurring (profiles 2 & 4 in Table 1), and as shown in the sample images, there is improved general image quality. It is feasible to image cine mechanical function during free-breathing with a moderate loss in image quality as compared to breath-holding, no loss in temporal resolution and without interruption in the imaging steady-state, using retrospective affine motion correction and a hybrid real-time/gated-segmented imaging sequence.

References: [1] Thevenaz P et al, "A Pyramid Approach to Subpixel Registration Based on Intensity", *IEEE Trans Image Proc*, 7(1):27-41,1998.

	End Diastole FBpre±std / Fbpost±std / BH±std	Mid-Contraction FBpre±std / Fbpost±std / BH±std	End Systole FBpre±std / Fbpost±std / BH±std
Profile 1 - IVS	0.10±0.03 / 0.12±0.02 / 0.18±0.03	0.11±0.04 / 0.14±0.03 / 0.19±0.04	0.11±0.03 / 0.13±0.04 / 0.20±0.04
Profile 2 - PPM	0.06±0.02 / 0.11±0.04 / 0.16±0.03	0.06±0.02 / 0.10±0.03 / 0.17±0.06	0.06±0.02 / 0.09±0.04 / 0.14±0.04
Profile 3 - LV LFW	0.08±0.01 / 0.08±0.02 / 0.12±0.04	0.07±0.02 / 0.08±0.03 / 0.10±0.03	0.05±0.02 / 0.06±0.03 / 0.08±0.03
Profile 4 - LV AFW	0.05±0.01 / 0.08±0.02 / 0.11±0.03	0.05±0.01 / 0.08±0.02 / 0.10±0.04	0.05±0.01 / 0.08±0.03 / 0.10±0.04
Profile 5 – RV PFW	0.04±0.01 / 0.06±0.03 / 0.13±0.05	0.04±0.02 / 0.05±0.02 / 0.09±0.03	0.03±0.01 / 0.04±0.02 / 0.06±0.03

Table 1: Maximum absolute normalized sharpness (max |Shnorm|) and standard deviation for 5 profiles (intraventricular septum, posterior papillary muscle, left ventricle lateral free wall, left ventricle anterior free wall, right ventricle posterior free wall) drawn on 3 cardiac phases (end diastole, mid-contraction, and end systole) for three image series (FBpre – pre-correction free breathing, FBpost – post-correction free breathing, BH – breath-hold image series). Averaged over 9 volunteer studies.

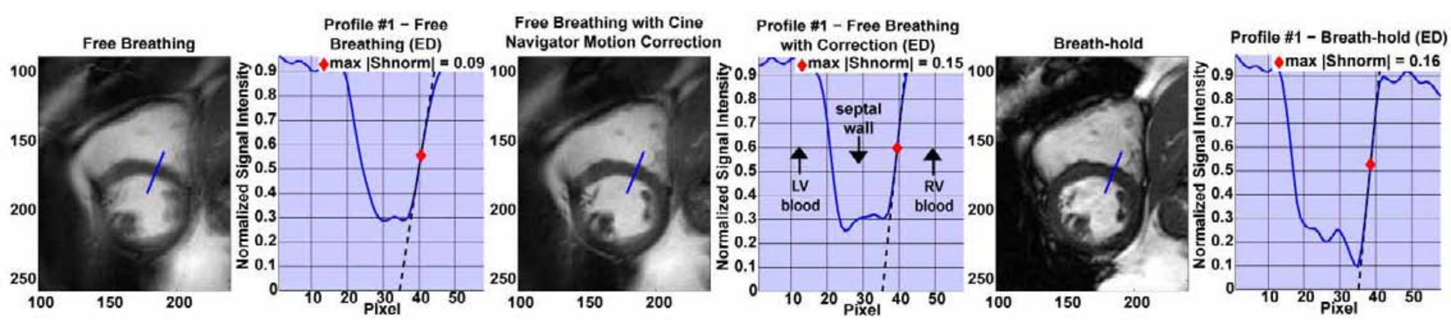

Fig. 1: Normalized signal intensity curves corresponding to a profile drawn on free-breathing (pre- and post-correction) as well as breath-hold cine-image series; the absolute maximum normalized sharpness (max|Shnorm|) is indicated in the top right corner of the profile graphs.