Motion Correction using Coil Arrays (MOCCA) for Free-Breathing Cardiac Cine MRI

P. Hu[1], S. Hong[2], M. H. Moghari[2], B. Goddu[2], L. Goepfert[2], T. H. Hauser[2], W. J. Manning[2], and R. Nezafat[2]
[1]Beth Israel Deaconess Medical Center, Boston, MA, United States, [2]Beth Israel Deaconess Medical Center

Purpose: Respiratory motion is one of main limitations of cardiac MRI. In this study, we evaluate the application of a motion compensation technique based on coil arrays (MOCCA) (1) for free-breathing cine MRI (2-4).

Theory: The presence of motion in MRI causes changes in the k-space signal. It is possible to detect the motion by analyzing the k-space signal change caused by the motion. This motion-induced signal change is modulated by the individual sensitivity profiles of the coils and the coils serve as additional "sensors" of the motion (Figure 1). Therefore, combining the signal from multiple coils has the potential to improve motion detection in MRI. In MOCCA, we construct the following function of k-space as a representation of the motion: $Q = corr\left(\hat{S}^{\gamma}(k)\big|_{k\in P,1\le\gamma\le N}, S^{\gamma}(k)\big|_{k\in P,1\le\gamma\le N}\right)$ where $corr$ calculates cross correlation coefficient (CCC), N is number of coils, and $S^{\gamma}(k)\big|_{k\in P,1\le\gamma\le N}$ is the vector formed by concatenating the magnitudes of non-phase-encoded k-space center lines acquired from all of the coils when the object is at a reference position, and $\hat{S}^{\gamma}(k)\big|_{k\in P,1\le\gamma\le N}$ is the vector corresponding to the position after motion. For simplicity, we herein refer to these vectors as MOCCA echoes and $S^{\gamma}(k)\big|_{k\in P,1\le\gamma\le N}$ as the MOCCA echo reference.

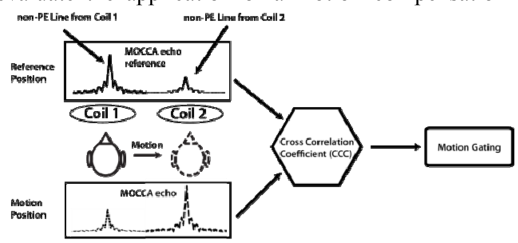

Figure 1: A schematic of MOCCA. The concatenated non-phase encoded (PE) lines (MOCCA echo) take advantage of the additional information provided by multiple coils, which serve as additional "motion sensors". The cross correlation coefficient between the MOCCA echoes before (reference position) and after motion represents the underlying true motion.

Methods: The respiratory self-gated cine MRI sequence was based on our standard clinical 2D breath-hold SSFP cine MRI sequence with retrospective ECG-gating, except that the MOCCA echo was acquired at the beginning of each k-space segment acquisition for each cardiac phase and 4 repetitions were acquired during free-breathing. The basic idea of our MOCCA self-gating algorithm was to choose one of the 4 repetitions for each k-space segment and cardiac phase based on the CCC between their corresponding MOCA echoes and the MOCCA echo reference (described below), so that respiratory motion related artifacts are suppressed in the reconstructed cine images. The MOCCA echo reference was defined as the set of MOCCA echoes acquired during a chosen heart cycle. As the end of expiration is the longest period during a respiratory cycle and is the period when the clinical breath-hold cine MRI is performed, it is desirable to choose MOCCA echoes acquired during this period as the MOCCA echo reference. To determine the MOCCA echo reference, we calculated the average of CCC values between every MOCCA echo and all the MOCCA echoes acquired during the same cardiac phase. We then chose the heart cycle corresponding to the set of MOCCA echoes with the highest overall average CCC values. In addition to the MOCCA self-gated cine reconstruction, the first acquisition of the free-breathing cine MRI data set was used to reconstruct a free-breathing cine image without self-gating. As a comparison, the standard breath-held cine MRI was performed on the same subjects and patients. The images from 8 healthy subjects were subjectively graded by an experienced evaluator and the blood-myocardium border sharpness was measured. The volumes (left/right ventricular end-diastolic/end-systolic volumes) and ejection fractions (EF) were measured based on MOCCA self-gated and breath-held images acquired on 15 patients referred to cardiac MR.

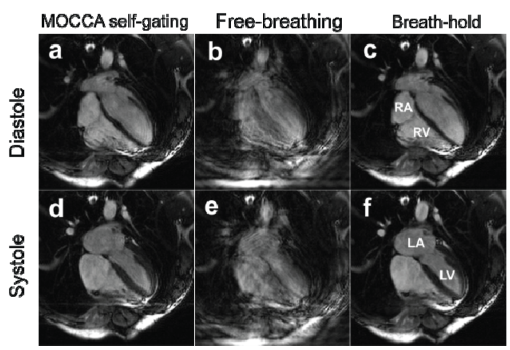

Figure 2: A comparison of cine images obtained from MOCCA self-gating (a,d), free-breathing without motion correction (b,e) and breath-hold (c,f).

Results: Example cine images acquired on a healthy subject with breath-hold, MOCCA self-gating and free-breathing without motion compensation are shown in Figure 2. The sharpness and subjective image scores are summarized in Table 1. LV and RV volumes and EF measurements based on the proposed self-gated cine MRI method are similar to breath-hold cine. The Bland-Altman analysis indicated that the 95% limits of agreement between the measurements based on the standard breath-hold cine and the proposed self-gated cine method were -7.8±15.0 ml for LVEDV, -2.7±8.7 ml for LVESV, -6.1±17.2 ml for RVEDV, -3.5±11.9 ml for RVESV, 0.4%±4.4% for LVEF, and 0.4%±5.4% for RVEF. **Conclusion:** MOCCA respiratory self-gating allows free-breathing cine MRI with similar image quality and clinical volume measurements with breath-hold.

References: 1. Hu et al., ISMRM 2010, p3058. 2. Uribe et al., MRM 2007;57:606-13. 3. Larson et al., MRM 2005;53:159-168 4. Liu et al., MRM 2010;63:1230-1237. **Acknowledgements:** The authors acknowledge grant support from NIH R01EB008743-01A2, AHA SDG-0730339N and AHA 10SDG4200076.

Table 1: Quantitative blood-myocardium border sharpness and subjective image scores of cine MRI using three methods (free breathing, breath-hold, and MOCCA self-gating). [Higher is better]

	Blood-myocardium border Sharpness			Subjective image score		
	SA	2CH	4CH	SA	2CH	4CH
MOCCA self-gating	0.50±0.19*#	0.43±0.16*#	0.46±0.15*#	3.4±0.7*#	3.5±0.7*#	3.5±0.5*#
Free-breathing (No Corr.)	0.28±0.15	0.28±0.14	0.24±0.12	2.0±1.0	2.4±1.1	2.5±0.9
Breath-hold	0.58±0.26*	0.62±0.22*	0.48±0.13*	4.0±0.0*	3.8±0.4*	4.0±0.0*

*: $P<0.05$ when compared with free-breathing. #: P =NS when compared with breath-hold. SA=short axis; CH=chamber.