Self-navigator for free-breathing 3D SSFP cardiac imaging: center of mass along the slice direction versus the image signal sum using the center of k-space.

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Introduction   Self-gating, which generates a respiratory gating signal from the k-space center data, is an emerging technique for performing free-breathing 2D SSFP imaging of the heart [1-4]. The k-space center signal is the sum of image signal, which depends on both the nature of motion and the slice geometry. Consequentially, motion sensitization may be ineffective within a slice and inconsistent among slices, leading to residual motion artifacts in images and slice misregistration within the 2D slice stack. In this study, we propose a gating signal generation method for 3D imaging that uses the center of mass of a projection onto the slice direction that is obtained after a Fourier transform of the k_z-axis points. It is hypothesized that this method provides superior respiratory motion artifact suppression when compared to the use of the center-of-k-space signal.

Materials and methods   Six healthy volunteers (mean age of 30 ± 7 years, IRB approved) were imaged on a GE Excite HDx 1.5T scanner with an eight channel cardiac phased array coil and vector ECG gating. A 3D short axis slab was positioned to cover the entire left ventricle. Pulse sequence parameters were TR/TE = 4.2 ms/1.9 ms, flip angle 50°, rBW = ±62.5 kHz, 256x160 imaging matrix, 26-28 slices (using partial k_z : 19-21 slices acquired), FOV=32 cm and phase FOV 0.65-0.85. Each cardiac phase acquired all slice encodings for a given phase encoding, with the even k_z encodings first, followed by the odd k_z encodings next. The cardiac phase acquisition was repeated for several RR intervals to cover the entire expected respiratory interval. In each TR, one extra readout before the phase encoding and readout prewinder but after the slice encoding was placed to acquire a slice encoded center-of-k-space signal. The position of a respiratory bellows positioned around the abdomen was recorded as well. Retrospective construction [5] was performed twice using two different respiratory gating signals 1) using the magnitude of the k-space center acquired at each cardiac phase (sum of image signal, ISUM), and 2) using the center of mass of the z-line profile that was obtained after Fourier transforming all points along the k_z axis (ZCOM) that are obtained at each cardiac phase. Low pass filtering (Hamming window, 0.5Hz cutoff frequency) was performed to remove noise and cardiac induced disturbances for respiration monitoring. For multiple coil acquisitions, the coil whose gating signal provided the highest correlation with the respiratory bellows was selected. For image analysis, one representative mid-ventricular slice was selected. SNR for myocardium and LV cavity blood was defined as mean signal S_{myo}, S_{blood} within a corresponding ROI divided by the standard deviation σ_{air} within a ROI of background air (correction for multiple coils and sum of square reconstruction was not used because it was constant for the two reconstructions). Blood-myocardium contrast to noise ratio ($CNR_{myo\text{-}blood}$) was defined as $(S_{blood}-S_{myo})/\sigma_{air}$. Image quality was assessed using two different scores: presence of blurring (0=severe 1=moderate 2=absent) and suppression of motion ghosting artifact (0=none, i.e. non-diagnostic) 1=poor 2=moderate 3=good 4=excellent, i.e. ghosting was absent.

	ZCOM	ISUM	p-value
SNR_{myo}	57 ± 10	44 ± 19	0.03
SNR_{blood}	152 ± 30	107 ± 46	0.01
$CNR_{myo\text{-}blood}$	95 ± 22	63 ± 28	0.01
Blurring	1.8 ± 0.4	1.2 ± 0.4	0.03
Ghosting	2.8 ± 0.4	2.0 ± 0.6	0.04

Table 1: Image analysis (*N*=6) for the ISUM and ZCOM reconstruction methods (see text)

Results   Two sets of 3D cardiac-phase resolved images were successfully reconstructed for each subject. Myocardium and blood SNR as well as their CNR was lower for the ISUM method vs. the ZCOM method (Table 1). Image quality from ZCOM was also better as measured by both the blurring and ghosting scores. A representative example can be seen in Figure 1. Better suppression of ghosting artifacts and less blurring of the myocardial border and papillary muscle can be observed in the ZCOM reconstructed images.

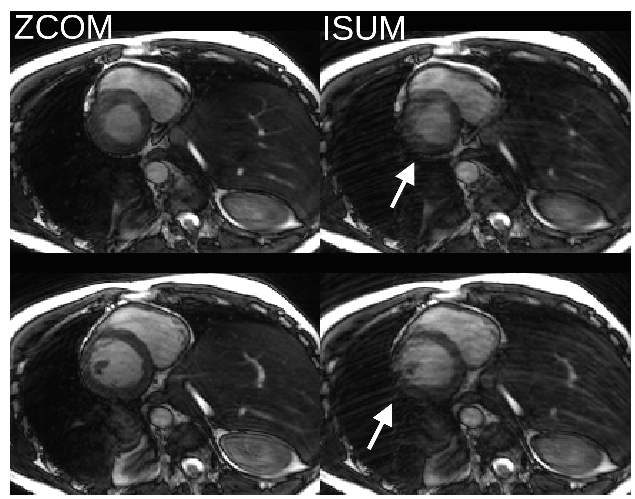

Figure 1 Midventricular short axis slice: systolic frame (top) and diastolic frame (bottom). Blurring and ghosting artifacts are observed in ISUM images.

Conclusion   The center of mass of the projection onto the slice direction was shown to provide a better respiratory gating signal resulting in better image quality when compared to self gating using the magnitude of the center of k-space only.

References   [1] Larson AC, et al, MRM 2004;51(1):93-102 [2] Larson AC, et al, MRM 2005;53(1):159-168 [3] Hiba B, et al, MRM 2006;55(3):506-513 [4] Crowe ME, et al, MRM 2004;52(4):782-788 [5] Thompson RB, Magn Reson Med. 2006 Dec;56(6):1301-10