3D free-breathing cardiac cine imaging with respiratory and cardiac self-gating and 3D motion correction

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INTRODUCTION

Free-breathing cardiac cine imaging with respiratory and cardiac self-gating provides flexibility and convenience for patient scans. Here we propose a 3D radial cardiac cine imaging technique that improves upon self-gating by adding 3D respiratory motion correction. The 3D respiratory motion signals are derived from multiple projections through the data used for image reconstruction at each time point. Cardiac self-gating is also achieved based on derived cardiac motion signals.

MATERIALS AND METHODS

3D cine imaging samples k-space with a stack of multi-echo radial acquisitions (radial projections filling in k_x-k_y plane and Cartesian encoding along k_z) [1]. Slice encodes at a given angle are acquired sequentially. The angle of successive projections are incremented π/r = 111.2^o (golden ratio r=1.618). Each scanned projection angles is unique, and this interleaving profile allows robust flexible time-resolved reconstruction [2].

The radial acquisitions at one angle along all slice encodes are 2D Fourier transformed to provide a xy-z profile every n_zTR (Fig.1 upper left corner), where n_z is the number of slice encodes. Summing up the xy-z profile along xy or z gives two image projections at each time point. These two image projections through time (xy-t and z-t) contain all 3 dimensions of motion within the FOV. Multiple adjacent projections at distinct angles (xy-t) are used to derive 2D image center of mass (COM) at x and y axes [3]. The COM along z of z-t profile is bandpass filtered to derive cardiac motion and respiratory motion along z, which are used for cardiac and respiratory self-gating [4]. The derived 3D respiratory motions are used for motion correction, by applying phase correction at each data point [5]. All coil data are combined for generating the xy-z profile. Sets of 20 consecutive projections incrementing by one projection (sliding window) through time are used for calculating the COM along x-y plane. The respiratory motion along z was used for respiratory self-gating. For the respiratory motions along three axes, 3D relative displacements were calculated and used for motion correction. Cardiac cine images are generated without sharing data among phases.

Cardiac imaging was acquired at 1.5T (GE EXCITE 14.0 with maximum gradient amplitude 33 mT/m, slew-rate 120 T/m/s) with an 8-channel cardiac coil. Self-gating 3D cine imaging was performed on seven subjects in short-axis views. Imaging parameters were: BW = ±125 kHz, FOV = 32-34 cm, reconstructed image size = 256x256, TR = 4.4 ms, n_z=10, slice thickness = 10 mm. The reconstructed images have a temporal resolution of 44 ms. Acquisition time was about 3.5-5 min.

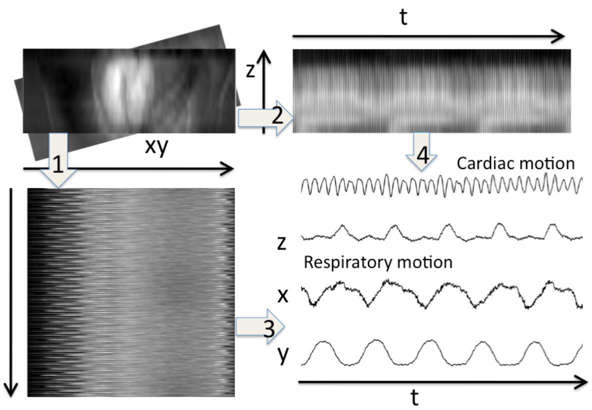
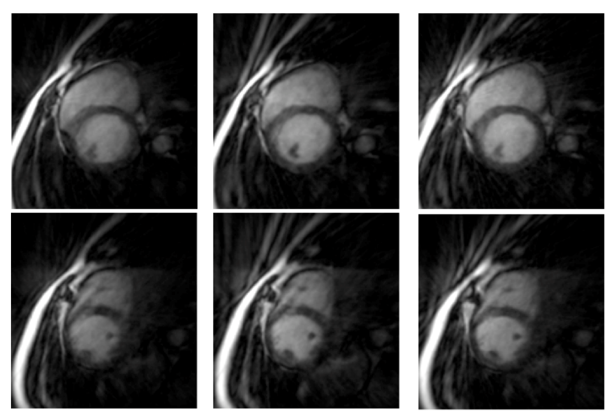


Fig.1 Radial acquisitions along slice encoding provide a profile (xy-z), from which cardiac motion and 3D respiratory motions can be derived. Projections at one angle through all the slice encodes are 2D Fourier transformed to obtain a xy-z profile (up left corner). For each projection (at time point t), the xy-z profile sums up along z (1) and xy (2). (3) 1D COMs at multiple projections are used to derive 2D COM coordinates x and y. (4) cardiac motion and respiratory motion along z are bandpass filtered out at specific frequencies from COM along z.



a) b) c)

Fig.3 Comparisons of two representative end-diastolic images obtained a) 100% data without respiratory self-gating or motion correction, b) 50% gating window with respiratory self-gating, and c) 100% data with motion correction. Note the moderate improvement in image quality in b and c.

RESULTS AND DISCUSSION

Fig.3 shows results from a volunteer; all images are cardiac self-gated. The results without gating or motion correction (Fig.3a) show noticeable blurring of the myocardial borders as well as the papillary muscles. The respiratory self-gated results that use 50% data provide sharper borders and papillary muscles (Fig.3b) but contain residual artifacts that diminish with motion correction (Fig.3c). The 3D COMs of the data with motion correction were also derived for comparisons. For the case shown in Fig.3, the biggest displacement was 6 pixels without motion correction and was reduced to 2 pixels after 3D motion correction.

This approach to deriving gating signals in three dimensions has proven to be robust. It can be combined with motion correction to improve image quality while reducing scan time. We observed that the calculated COMs along x and y axes were within reasonable ranges, while the COMs along z were suffering from low spatial resolution along the slice encoding direction.

CONCLUSIONS

We propose a respiratory and cardiac self-gating with 3D respiratory motion correction technique for free-breathing cardiac cine imaging. Preliminary results show improvement in image quality and reliability of self-gating signals.

REFERENCES

1. Liu J., *et al.*, Proc. ISMRM 2007, p3868.
2. Winkelmann S., *et al.*, IEEE TMI, 26, p68, 2007.
3. Larson AC, *et al.*, MRM, 51, p93, 2004.
4. Liu J, *et al.*, 17th ISMRM, p1804, 2009.
5. Stehning C, *et al.*, MRM, 54, p476, 2005.