Self-gated PROPELLER cine cardiac imaging: Simultaneously tracking the cardiac pulsation and the respiratory motion

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Introduction

In order to reduce motion-related artifacts, breath-holding and ECG trigger is generally required for cardiac MRI. However, in the clinical practice, some patients can not perform voluntary breath-hold and the ECG trigger system sometimes fails due to the interference of magnetic field and gradient system. To solve this problem, several self-gating techniques including radial encoding[1] and variable-density spiral techniques[2] were reported. In our study, a self-gating technique designed for MR cine cardiac imaging, involving both PROPELLER encoding[3] and 2D correlation analysis, was proposed. Using this method, the patient can freely breathe during the scan of cine cardiac imaging. Moreover, using correlation analysis, the cardiac motion synchronization data was calculated directly from MRI signal and was applied to retrospective cine cardiac image reconstruction. Therefore, the ECG trigger was not necessary at the scan duration.

Material and Methods

A PROPELLER-encoded Turbo-Field Echo (TFE) sequence was implemented on a 3T whole-body MR system (Achieva 3T, Philips) for self-gated cine cardiac imaging. Three subjects participated in this study. For each subject, one set of 1024 PROPELLER blades were collected by the sequence described above with the following parameters (FOV:30cm, TR/TE:2.9ms/1.6ms, flip angle:30 degree, blade size:12x256, PROPELLER rotation step: 6degree). The acquired blades were transferred to personal computer with Matlab® system (Mathworks, Natick, MA, USA) for self-gating PROPELLER reconstruction algorithm.

The self-gating reconstruction included three steps:1) extracting the trace of respiratory motion and the cardiac motion, 2) rearrange PROPELLER blades according to the motion condition, and 3) regridding the non-Cartesian k-space and transforming to the image domain. To extract the motion information, the low resolution blades of PROPELLER encoding MRI were be transformed to image domain and a ROI covering the myocardium was selected and all of the blades were cropped with the selected ROI. With the cropped images, correlation coefficients between first blade and the rest blades was calculated to extract the cardiac motion. Then, the blades of PROPELLER encoding MRI were separated into several groups (around 12 groups, varied according to the heart rate of the volunteer and the blade sizes) according to the calculated cardiac phases. Finally, the respiratory self-gating algorithm reported by Huang TY et al.[4] and the Kaiser-Bessel window regridding method[5] were applied on each group to yield high resolution cardiac images.

Results

Figure 1 shows the motion trace extracted from k-space raw data obtained from one of the volunteers. Note that both cardiac motion and respiratory motion were mixed in this trace. Nonetheless, the cardiac motion most likely dominated the whole pulsatile curve owing to the following observation. The period of The pulsatile pattern was about 12 blades(64ms per blade) and, was therefore near to the R-R interval (~750ms) we measured from this volunteer. Figure 2 shows the selected cardiac phases from the reconstructed PROPELLER images. No prominent motion artifacts were found. At the end-systole phase, the cardiac image (Fig.2f) shows less sharp than the other phases

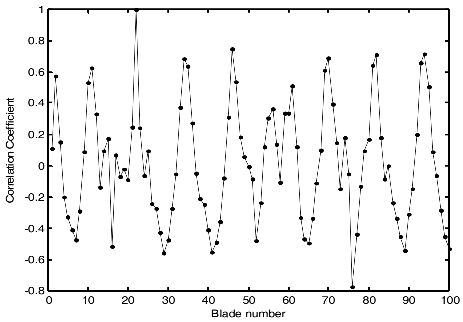

Fig.1 Extracted motion trace by correlation anaylysis.

Discussion and Conclusions

In this study, the k-space center over-sampling property of PROPELLER encoding and correlation analysis were applied to cardiac imaging without either ECG or breath-holding. The correlation analysis yielded pulsatile curve which was applied to rearrange the k-space data. The resulted cine images showed clearly the cardiac cycle. Therefore, the cardiac phases seemed identified correctly. In the systole phase, the images shows more blur, which may be caused by the faster cardiac motion during this period. Further reducing the acquisition time of one blade (currently 64ms) may improve the image sharpness.

Compared to the radial self-gating method, the temporal resolution of the extracted motion trace in current study was lower (several phase encoding line in PROPELLER vs. only one line in radial scan). The reconstructed cine phase number was hence less than the radial-base self-gated techniques. Nonetheless, the PROPELLER encoding techniques can be considered as conventional Fourier encoding albeit with different in-plane rotation angle at each shot. Thus, the self-gating method with PROPELLER should be compatible with most of the Fourier base cardiac imaging techniques. To apply this method on high temporal resolution cine imaging, further improving the temporal resolution may be achieve by using parallel imaging techniques or segmented-EPI readout. In conclusion, PROPELLER self-gating cardiac imaging, which can reduce the setup complexity (i.e. ECG cables) and extend the cardiac imaging to the patients who cannot perform voluntary breath-hold, can be a useful tool in the clinical practice.

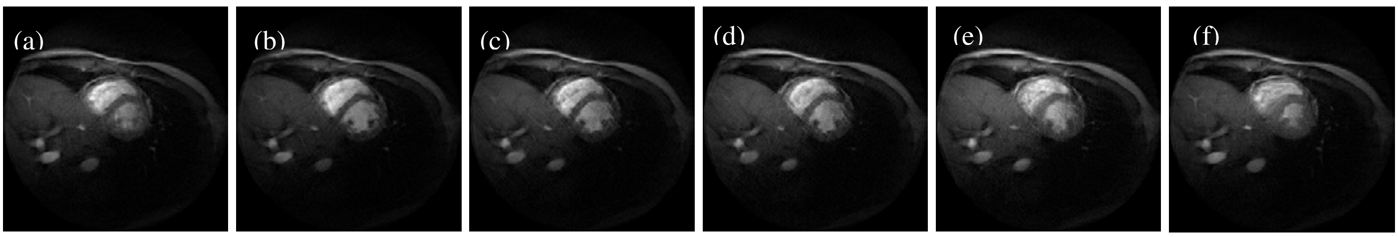

Fig.2 The reconstructed images using PROPELLER encoding and correlation analysis. (a) (b) (c) are images during diastole, (c) is the end-diastole image. (d) (e) (f) are images during systole, (f) is the end-systole image.

Reference

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