Cardiac and respiratory double self-gated cine MRI in the mouse at 7 T

B. Hiba[1,2], P. Croisille[1,3], O. Beuf[1,4], M. Janier[1,3]

[1]ANIMAGE, Lyon, France, [2]Rhône-Alpes Genopole, Lyon, France, [3]UMR CNRS 5515 Creatis, Lyon, France, [4]CNRS UMR 5012, Lyon, France

Introduction

ECG-gated cardiac magnetic resonance imaging in the mouse at 7T presents many technical difficulties due to the high heart rate (450-550 bpm), blood-flow-related artefacts, radiofrequency and gradient interferences with ECG signal. A respiratory gating is also necessary to avoid additional blurring in reconstructed images. In this study, we propose to use the self-gated MRI technique to derive cardiac cycle timing information directly from MR signal and also to detect and eliminate respiratory motion artefacts in mouse cardiac cine imaging.

Methods:

The self-gated Projection-Reconstruction (PR) cardiac cine technique [1] is based on the fact that echo-peak complex values, acquired in K-space center with no phase encoding, correspond to the sum of the transverse magnetization across the entire image volume. Any variation of this volume due to cardiac and/or respiratory motions leads to proportional changes in peak values of consecutively acquired echoes. These changes can be used to generate a retrospective gating signal, allowing elimination of motion artefacts.

A PR sequence and a FLASH sequence were used to acquire respectively self-gated and ECG-gated cardiac cine images. Imaging was performed on a 7 T magnetic resonance scanner equipped with a 400 mT/m gradient system (Bruker, Ettlingen, Germany), with a 72 mm whole body coil for RF excitation and a 15 mm surface coil for MR signal reception. Short-axis cine images with a 25 mm^2 FOV, 256^2 pixels, 1 mm slice thickness, 7/3.5 ms TR/TE, 64 KHz bandwidth and 20° flip-angle were obtained with 512 views for PR and with 256 views for Cartesian acquisitions. N_{pe} PR measurements were continuously achieved to get the same total acquisition time as the Cartesian acquisition, which depends on heart rate and signal averaging step number.

A home-built C++ program was used to reconstruct self-gated cardiac cine images. In our approach, gating signal is firstly extracted from echo peaks. After low band pass filtering, cardiac cycles are determined using a peak detection algorithm. Only cardiac cycles whose duration is between two given thresholds are selected on the self-gating signal. Data acquired during respiratory motion are also eliminated using a semi-automatic procedure. Selected data were finally reorganised according to their position inside the cardiac cycle interval before being reconstructed using a gridding algorithm [2] to get the final cine sequence.

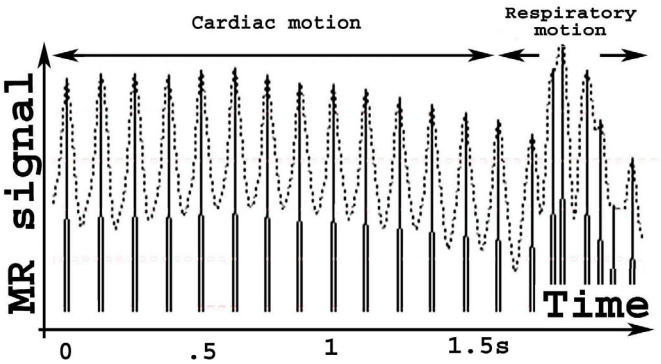

FIG.1. Filtered self-gating signal of 14 cardiac cycles followed by one inspiration. Vertical lines present retrospective trigger points.

Results:

FIG.1 shows a self-gated signal with a 7 ms temporal resolution and the retrospective trigger points obtained in a mouse with a 480 bpm heart rate. Only data acquired during detected cardiac cycles of 110-135 ms were selected for image reconstruction. In this way, the major part of data acquired during potential arrhythmia or during respiratory motion was automatically eliminated. Data corresponding to residual non desired modulations of the self-gating signal were manually eliminated to avoid motion artefacts. A rejection rate of 25-30% of the total acquired data was finally obtained.

Cardiac cine images obtained with a total acquisition time of 2.5 min using self-gated and ECG-gated cardiac MRI techniques present different characteristics (FIG.2). This is due to the difference in the K-space scanning mode, the difference of steady-state condition and respiratory motion artefacts elimination with self-gating technique.

Subtle anatomical structures such as cardiac vessels were better delineated on self-gated images (FIG.2 C vs. D.), which is probably due to the elimination of respiratory motion artefacts with the self-gating technique.

SNR was measured in the region of the left ventricular (LV) cavity in the end-systolic images acquired with the two techniques and reconstructed with the same number of frames (FIG.2). SNR values of 17.6 and 19.4 were respectively obtained in self-gated and ECG-gated images. The difference of SNRs could be explained by the elimination of data acquired during respiratory motions in self-gated datasets.

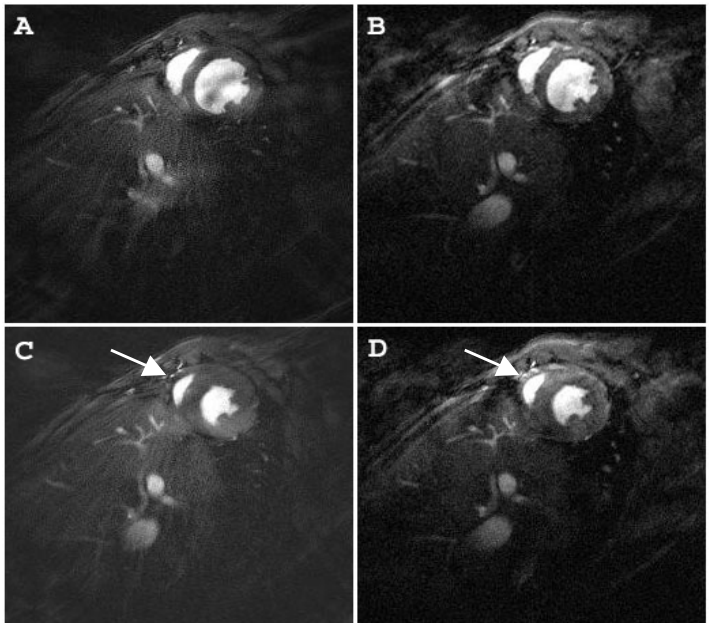

FIG.2. End-diastolic and end-systolic Self-gated (A,C) and ECG-gated (B,D) short-axis images in the mouse at 7T.

Conclusion:

Using the SG technique, a double retrospective respiratory and cardiac gating was achieved to perform cardiac cine imaging in the mouse at 7T. This technique provides many advantages such as much shorter installation time of the mouse in the scanner, retrospective arrhythmia rejection, whole RR cardiac cycle sampling. On the other hand, this technique may suffer from radial streak artefacts and it requires a more sophisticated reconstruction algorithm.

[1] Larson, Magnetic Resonance in Medicine 51:93-102 (2004).

[2] Schomberg, IEEE Trans Med Imag 14:596 – 607 (1995).