Improved Navigator Technique for Cardiac Cine Imaging during Free Breathing

B. A. Jung[1], J. Hennig[1]

[1]Dept. of Diagnostic Radiology - Medical Physics, University Hospital, Freiburg, Germany

Introduction

MR assessments of global ventricular function are typically based on 2D measurements with balanced SSFP pulse sequences. Additional methods to quantify regional myocardial wall motion are tagging, phase contrast (PC) velocity mapping, and DENSE. All of these these acquisitions are typically performed in multiple breath-held 2D measurements. One drawback of this approach are the limitations in spatial and temporal resolution due to the length of the breath-hold period. Navigator echoes (NE) can be used to overcome these limitations by avoiding the need for a breath-hold with the drawback of extending the total acquisition time. However, in standard NE implementations a single navigator position represents a complete RR interval while significant motion of the rib cage and the heart can occur during the duration of a complete cardiac cycle. Such incosistencies can lead to motion artifacts and falsified velocities or displacements of the motion describing data. A potential solution to this problem is the use of a previously described navigator-guided techniques using one NE per cardiac cycle with pre- and post navigator information [1] (Fig.1a) but with a poor scan efficiency [2]. In this work we propose a prospective respiratory gating technique with multiple NE for the assessment of ventricular function during free-breathing in order to improve the scan efficiency. The technique is demonstrated with bSSFP and PC imaging.

Methods

NE were periodically inserted into a continuously acquiring bSSFP cine sequence and a PC cine sequence for the tracking of the respiratory motion. An α/2 flip-back pulse was inserted prior to and after each NE in order to restore the steady state [3].Improved navigator gating was achieved using two NE per cardiac cycle in combination with real-time decision criteria based on signals from successive navigator echo pairs in the center and at the end of the cardiac cycle (Fig.1b). Data acceptance or rejection was based on the combined information from adjacent navigators for the two resulting data blocks inside a cardiac cycle independently treated. The total time needed for the two NE including their evaluation following the second NE was 55 ms for bSSFP imaging and 40 ms for PC imaging. A 5-mm acceptance window in end expiration was used for all measurements. All measurements were performed on a 1.5 T Magnetom Sonata (Siemens Medical Solutions, Erlangen, Germany). Image acquisition parameters for bSSFP imaging were as follow: TR=3 ms, data matrix 144 x 256, temporal resolution=47 ms, slice thickness = 8 mm, flip angle 35-50°. PC images were acquired with a black blood k-space segmented gradient echo sequence with TR=6.4 ms, data matrix 96 x 256, flip angle = 15°. Velocity encoding was performed in an interleaved order by adding a bipolar gradient in read, phase, and slice direction. The velocity encoding value (venc) was set to 20 cm/s in-plane and 30 cm/s through-plane according to the typical velocity values occuring in the wall motion of the left ventricle. A temporal resolution of 52 ms was achieved by using view sharing technique.

Results

Fig.2 shows representative bSSFP images of a basal slice in a normal volunteer acquired with different acquisition schemes: a) one NE per cardiac cyle , b) two NE per cardiac cycle, c) breath-hold. Fig. 3 displays magnitude images of the black-blood PC sequence in a normal volunteer acquired with two NE per cardiac cycle. For all images the left column shows a diastolic frame, the right column a systolic frame.

Discussion

An efficient strategy for the combination of NE based respiratory gating for cardiac cine imaging was demonstrated in this study. The novel navigator technique in combination with bSSFP imaging provides a useful tool for free-breathing acquisitions with improved image quality, e.g. with applications in pediatric cardiac MRI. Furthermore, this approach allows for an improved analysis of cardiac function with phase contrast cine imaging. The use of more NE per cardiac cycle would slightly increase the scan efficiency but with the loss of information due to the additional time of the NE. The use of a motion-adapted gating technique based on k-space weighting would also increase the scan efficiency without significant motion artifacts [4]. We have also used the technique to improve the acquisition for the analysis of velocity fields to deviate surrogate parameters describing the fiber structure of the left ventricle [5].

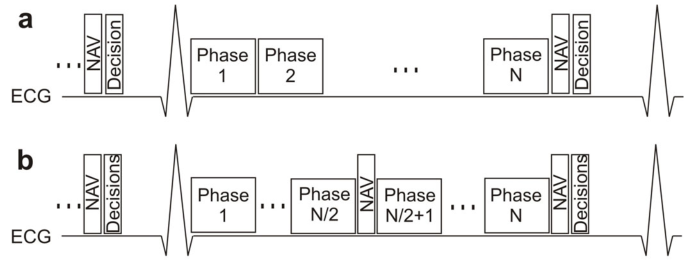

Fig.1: Acquisition strategies for the navigator-gated free-breathing measurements with one (a) and two (b) NE per cardiac cycle.

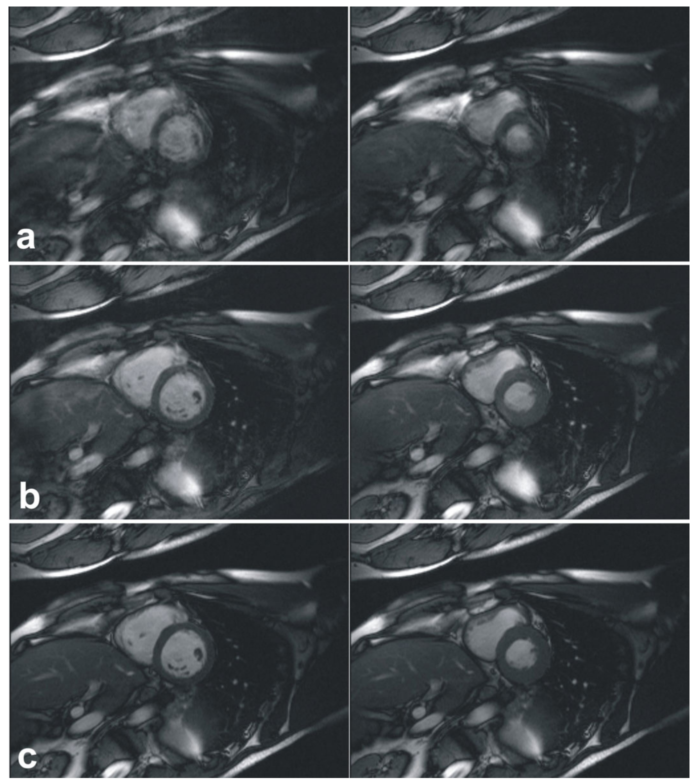

Fig.2: balanced SSFP images acquired with one NE (a), two NE (b) during free breathing and breath-hold acquisition (c).

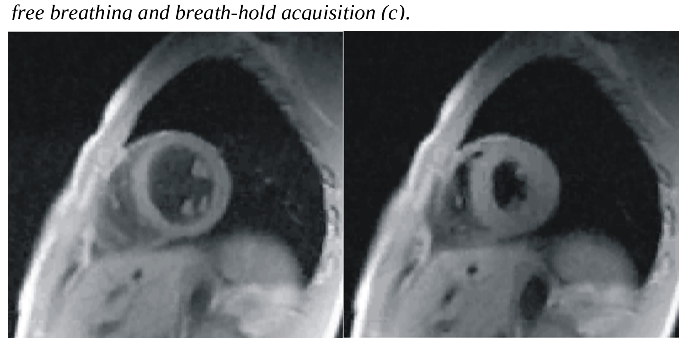

Fig.3: magnitude images of PC data acquired during free breathing.

References

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