Simultaneous acquisition of image and navigator slices using CAIPIRINHA

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Introduction

Respiratory organ motion is a complicating factor in many treatments. Especially for dynamic dose delivery such as in tumor therapy, exact knowledge of organ motion and its influence on the dose distribution is crucial. Siebenthal et al [1] recently purposed a novel respiratory correlated MR imaging method that acquires a full 2D sagittal navigator image instead of the commonly used one-dimensional diaphragm navigator. This method allows for tracking vascular structures during complete breathing cycles with minimal out-of-plane motion. The 4D-MRI (three dimensional and one temporal dimension) model of organ motion requires rapid acquisition of 2D images. It also requires high contrast between liver tissue and vessels, in contrast to conventional (and less precise) methods that only detect the diaphragm position. High vessel-tissue contrast is generated with balanced Steady State Free Precession (bSSFP) sequences giving bright vessel signal enhancement. In the original method, image and navigator slices were acquired interleaved. Since the navigator image is used to estimate the exact position and shape of organ, a time lag between image and navigator could lead to discrepancy in images and even to building of incorrect models. In this paper, we describe a new approach to image and navigator acquisition based on multislice Controlled Aliasing in Parallel Imaging Results in Higher Acceleration (CAIPIRINHA) [2], which allows a true simultaneous acquisition with consequent decrease of lag and increase of temporal resolution.

Methods

A modified bSSFP sequence which excites two slices simultaneously, namely image and navigator, was implemented. This was achieved by running two RF pulses with slice selection gradients of opposite polarity, thus achieving moment compensation for both slices at echo and repetition time (fig 1, left). Image and navigator are encoded at the same time, so they will appear superimposed on top of each other in the image. Phase cycling of $+\pi/2$ for the first, and $-\pi/2$ for the second RF pulse was implemented in order to achieve a shift of the superimposed images with respect to each other and to avoid the bSSFP signal voids [2] [3]. Image slices were acquired at different positions to cover the whole liver, while navigator slices were always acquired at the same position [1]. While a linear ramp preparation was performed for each image slice, the navigator slice was kept in the steady state (fig 1, right). If the image slice was acquired at the same position of the navigator, only one RF pulse was applied, and therefore only the image slice is acquired. This approach provides better temporal resolution and saves unnecessary scans. Image reconstructions were performed offline with adapted sensitivity encoding (SENSE) algorithms implemented in MATLAB (The Mathworks, Natick, MA). In vivo measurements were performed on three healthy volunteers using a 1.5 T whole-body system (MAGNETOM Espree, Siemens AG, Healthcare Sector, Erlangen, Germany) equipped with a six-channel surface body coil and a nine-channel spine coil. Liver images were acquired using the described bSSFP sequence with the following parameters (FOV: (235 × 251) mm; matrix 120 × 128; thickness: 5 mm; partial Fourier factor: 6/8; acquisition bandwidth: 1000 Hz/pixel; TR 3.18 ms; TE 1.84 ms; flip angle: 50°; TAcq: 303 ms).

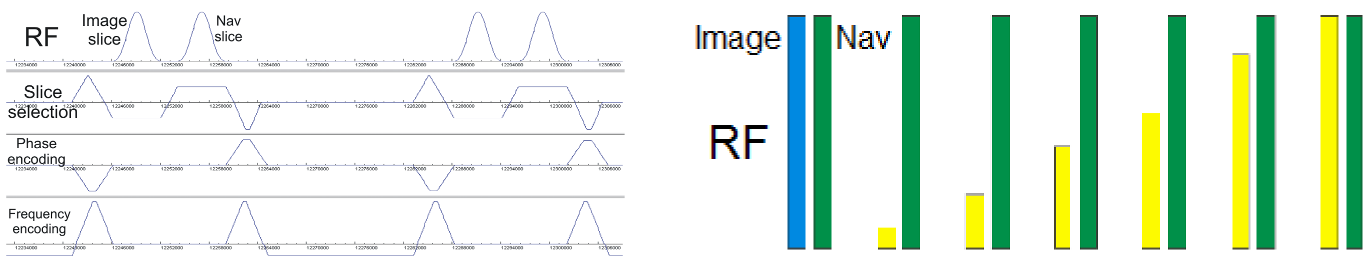

Figure 1: Sequence pulse diagram (left), and preparation pulses for image and navigator slices (right)

Results and Discussion

Typical superimposed image as well as reconstructed image and navigator slice are shown in figure 2. Blood vessels provide bright signal on navigator image and they can be readily used for retrospective stacking. Strong fat signal is responsible for dark bands on reconstructed images, as we can see from figure 2, that occur after image reconstruction. However for our application the reconstructed images are of satisfactory quality since modeling of liver motion relies on tracking blood vessels and estimating liver contour. It is also observed that patient weight is correlated with quality of reconstruction, since more fat produces more artifacts. Fat suppression could be a solution to this problem, and in future work assessment of its efficiency will be investigated.

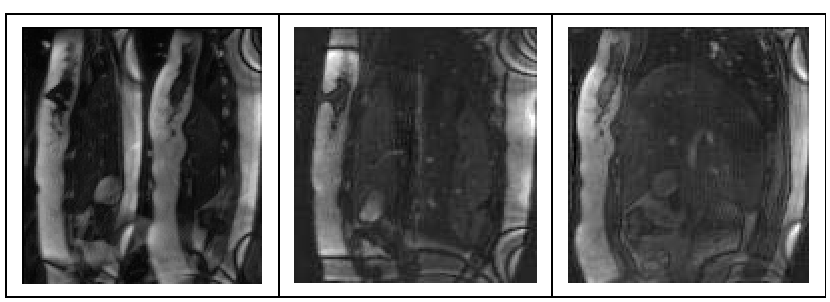

Figure 2: Superimposed image and navigator (a), reconstructed image (b) and navigator slice (c)

References:

[1] Siebenthal MV et al 4D MR imaging of respiratory organ motion and its variability. *Phys. Med. Biol.* (2007), **52**(6), pp. 1547-1564; [2] Breuer at al, Controlled aliasing in parallel imaging results in higher acceleration (CAIPIRINHA) for multi-slice imaging, *Mag. Reson. Imag.* (2005); [3] Stäb et al, CAIPIRINHA accelerated SSFP imaging, *Mag. Reson. Imag.* (2010)