Myocardial perfusion imaging using CAIPIRINHA accelerated multi-slice saturation recovery TrueFISP

D. Stäb[1], C. O. Ritter[1], A. Weng[1], M. J. Beer[1], M. Gutberlet[1], D. Hahn[1], and H. Köstler[1]
[1]Institut für Roentgendiagnostik, Universitätsklinikum Würzburg, Würzburg, Bavaria, Germany

Introduction:

Saturation recovery (SR) prepared TrueFISP sequences are widely in use for myocardial perfusion imaging because of a high intrinsic signal-to-noise ratio (SNR). Since the image acquisition is limited by the heart cycle, a complete coverage of the heart with consecutively acquired slices is difficult. Parallel imaging techniques are required significantly reducing the acquisition time per slice (1) and hence the SNR.
CAIPIRINHA accelerated multi-slice imaging (2) offers the possibility to significantly increase the number of slices acquired by exciting several slices simultaneously while conserving the acquisition time per slice and consequently the SNR.
However, due to the constraint to keep the steady state condition of the sequence (3), the implementation of CAIPIRINHA into TrueFISP is difficult. A segmented image acquisition as previously proposed (4) is not applicable due to the applied SR magnetization preparation. Aim of this study was to develop a new approach combining CAIPIRINHA multi-slice imaging with the SR TrueFISP myocardial perfusion sequence, in order to achieve a full coverage of the myocardium.

Material and methods:

To realize the phase cycles required by CAIPIRINHA and to meet the steady state condition of TrueFISP at the same time, for each slice individual constant phase increments Δ_n between succeeding multi-slice RF pulses were implemented. Phantom experiments and 12 slice perfusion studies were performed with CAIPIRINHA implemented to excite two slices simultaneously. According to a desired shift of a ½ FOV between two simultaneously excited slices the phase increments were chosen to be Δ_1 = +90°, (0°,90°,180°,270°,0°, … RF phase cycle) for the first and Δ_2 = -90° (0°,270°,180°,90°,0°, … RF phase cycle) for the second slice.
All experiments were performed on a Siemens Symphony 1,5T system using an 8 channel body array for signal reception and a SR TrueFISP sequence implementing the following parameters: FOV: 350x262.5mm^2; matrix: 128x80; thickness: 10mm; distance between simultaneously excited short-axis/long-axis slices: 40mm/10mm; TR: 3.2ms; TE: 1.59ms; TI: 104ms; flip angle: 50°; partial fourier factor: 6/8; T_{Acq}: 205ms. An adapted offline GRAPPA (5) reconstruction (R=3) was used to separate the overlapping slices.
The myocardial perfusion experiments were performed according to the prebolus approach (6). Every 2 heart beats 6 consecutive saturation recovery CAIPIRINHA acquisitions were performed sampling the CA bolus (Multihance 1ml/4ml) in all 12 slices by 20 measurements over 40 heart beats.

Results:

12 slice quantitative myocardial perfusion imaging could be performed successfully using a dedicated SR TrueFISP sequence. Although using the multi-slice excitation the SAR limit was not exceeded at 1.5 T. The adapted GRAPPA reconstruction separated the overlapping slices in both phantom and in vivo experiments without visible reconstruction artefacts (fig 1). As expected the SNR was unchanged in comparison to single-slice imaging since the acquisition time per image was not reduced and no significant noise enhancement was found to be introduced using parallel imaging. Single-voxel signal-intensity-time-courses of four different regions of the myocardium are shown in fig. 2. Being obtained from single voxels they demonstrate the high SNR.

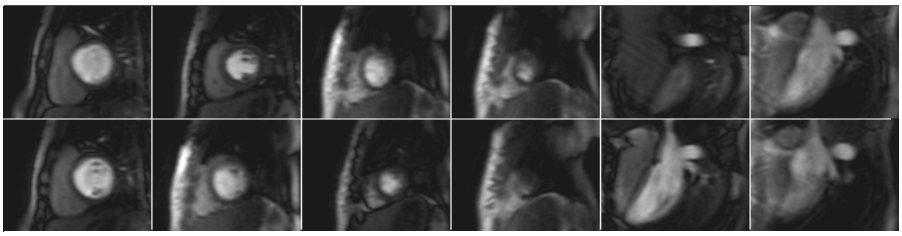

Fig. 1: Images of an in vivo experiment showing the passage of the CA through the left ventricle of the human heart in 8 short axis and 4 long axis slices.

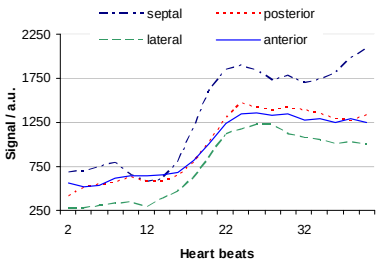

Fig. 2: Single-voxel signal-intensity-time-courses measured in the anterior, lateral, posterior and septal wall.

Conclusion:

Based on a combination of a SR TrueFISP sequence with CAIPIRINHA multi-slice imaging, providing steady state in all individual slices, the acquisition of 12 slices during one first-pass experiment could be achieved. Image quality and signal-intensity-time-courses in the blood pools and the myocardium were comparable to that attained with single slice excitation techniques. Consequently the presented CAIPIRINHA SR TrueFisp imaging technique allows whole heart perfusion measurements at a high signal-to-noise ratio and is expected to be suitable for myocardial blood-flow quantification even on a pixel by pixel basis.

References:

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