CAIPIRINHA accelerated Myocardial First-Pass Perfusion Imaging with High Resolution and Extended Coverage – A Patient Study

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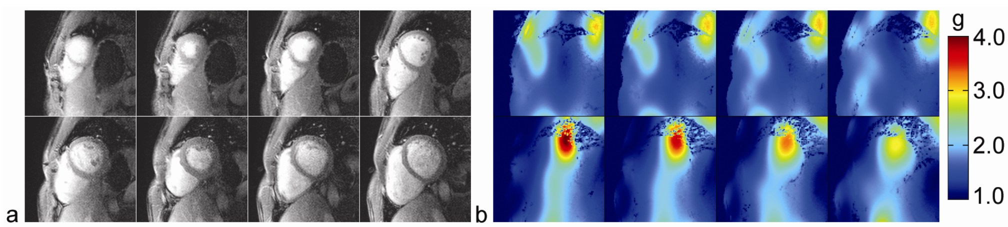
Introduction:

Contrast enhanced myocardial first-pass perfusion MRI is restricted by the cardiac cycle and typically a trade-off has to be found between spatial resolution and anatomic coverage. Recently, the simultaneous multislice Parallel Imaging technique CAIPIRINHA (1) has proven its efficiency for extending the anatomic coverage in myocardial first-pass perfusion MRI (2). Moreover, by employing acceleration factors higher than the number of simultaneously excited slices, the technique additionally facilitates high spatial resolution (3). In this work, in-vivo studies of volunteers and patients are presented, demonstrating the high potential of the technique for high resolution myocardial first-pass perfusion MRI with large anatomic coverage.

Material and Methods:

In CAIPIRINHA simultaneous multislice imaging, multi-band radio frequency (rf)-pulses are employed to excite several slices at the same time. By providing the different slices with individual rf phase cycles, the slices are shifted with respect to each other in the FOV, facilitating the separation of the slices using conventional Parallel Imaging techniques. The technique also supports the application of acceleration factors higher than the number of simultaneously excited slices. The phase cycled multi-band CAIPIRINHA excitation simply has to be applied to a conventionally in-plane accelerated measurement. Employing this concept to myocardial first-pass perfusion imaging facilitates measurements with significantly extended anatomic coverage and high spatial resolution.

Myocardial first-pass perfusion measurements on 5 volunteers and 4 patients (myocardial infarction) were performed on a 3T Magnetom TRIO system (Siemens Healthcare Sector, Erlangen, Germany) using a dedicated 32 channel cardiac array (Siemens Healthcare Sector, Erlangen, Germany) for signal reception and an ECG-triggered Saturation Recovery FLASH sequence for imaging (FOV: 320 x 300-360 mm^2; matrix: 160 x 150-180; TI: 110-125 ms; TR: 2.8 ms; TE: 1.44 ms; T_{Acq}: 191-223 ms; slice thickness: 8 mm; distance between simultaneously excited slices: 24-32 mm; spatial resolution: 2.0 x 2.0 mm^2; flip angle: 10°; Measurements: 40). CAIPIRINHA was applied with two slices excited at the same time (phase cycle in slice1/slice2: 0/π; shift between simultaneously excited slices: ½ FOV) and additional 2.5 fold undersampling in-plane, resulting in an overall effective acceleration factor of R = 5. According to the heart rate, during every RR interval, 3 or 4 consecutive saturation recovery CAIPIRINHA acquisitions were performed, tracing the first-pass of the contrast agent (Gadovist, 4 ml) through the myocardium in 6 or 8 neighbouring slices respectively. Image reconstruction was performed using an offline GRAPPA (4) reconstruction in combination with an additional calibration scan. Additional noise scans were performed in order to quantify the noise enhancement introduced by the GRAPPA reconstruction (5).



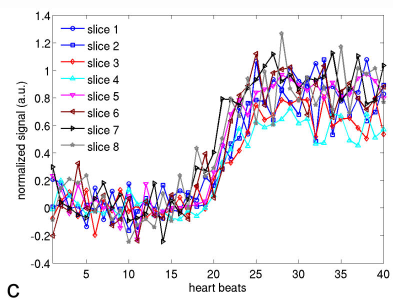


*Fig. 1: Representative results of an 8-slice volunteer study. Shown are the pass of the contrast agent through the myocardium **(a)**, corresponding g-factor maps for the GRAPPA reconstruction **(b)** and normalized and baseline corrected single voxel intensity time curves derived from the anterior wall in the eight different slices **(c)**.*

Results:

Myocardial first-pass perfusion imaging could be successfully performed with a high spatial resolution of 2.0 x 2.0 mm^2 and an anatomic coverage of 6 to 8 slices every heart beat. Fig. 1 shows images, geometry factors and intensity time curves for a representative volunteer study. In Fig. 2, images of a patient study are presented. For all studies, the slice separation and image reconstruction could be performed without residual artefacts (Figs. 1a and 2a) even in presence of severe breathing motion (Fig. 2a). In general, the g-factor maps indicate moderate noise enhancement (Fig. 1b) that can be seen throughout the image. However, in all cases, the myocardium is well distinguishable from the lung tissue and the contrast enhancement is clearly observable in all parts of the myocardium. For the patient study displayed in Fig. 2, the hypoperfused area of the myocardium is conspicuous (arrows). For comparison, corresponding slices of a subsequently performed late enhancement examination are depicted.

Discussion:

Employing CAIPIRINHA with acceleration factors higher than the number of simultaneously excited slices facilitates high resolution myocardial first-pass perfusion imaging with extended anatomic coverage. By exploiting coil sensitivity variations in slice and phase encoding direction, the technique generally provides low g-factor noise, high image quality and is expected to be suitable for pixelwise blood flow quantification. According to the heart rate, 6 to 8 slices can be acquired every RR interval while providing a high spatial resolution of 2.0 x 2.0 mm^2. With image acquisition times of 191 ms, the technique also allows for stress examinations in 6 slices up to a heart rate of 104 bpm. Providing short image reconstruction times and being easy to implement, the presented technique is suitable for an application in clinical routine.

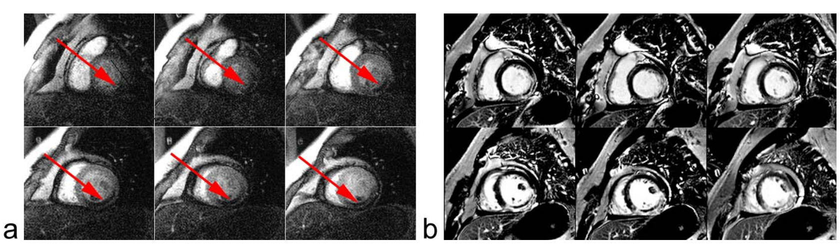


*Fig. 2: Results of a patient study with 6 slices. **a:** Pass of the contrast agent through the myocardium. The hypoperfused area is clearly visible (arrows). **b:** Results of the corresponding late enhancement examination.*

References:

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