Radial CAIPIRINHA for rapid 6 slice myocardial perfusion without magnetization preparation

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PURPOSE: First-pass myocardial perfusion imaging offers a valuable method for characterizing blood flow of myocardial tissue. Nearly all modern first-pass myocardial perfusion techniques use a saturation preparation pulse and ECG gating [2]. An alternative approach is to use a spoiled gradient echo (SPGR) steady-state acquisition that acquires images rapidly enough that ECG gating is not needed [3, 4]. This approach was implemented in either 3D or 2D by using the SPGR sequence to maintain steady state. The 2D scheme was performed in both single slice and three slices interleaved which increases the coverage of the heart [5, 6], but complete heart coverage without losing the temporal resolution of the first pass myocardial perfusion imaging is still desired. A controlled aliasing multi-slice parallel imaging technique named CAIPIRINHA (or CAIPI) [7] was proposed as a powerful method to achieve increased imaging coverage without losing temporal resolution and image quality. The CAIPI method uses alternating phase multi-band RF pulses to excite multiple slices simultaneously, and can recover the superimposed slices by exploiting the phase modulation pattern along with coil sensitivity encoding. In this study we propose to combine the simultaneous multi-slice excitation imaging technique and the ungated interleave method to study its utility for first-pass myocardial perfusion imaging.

METHODS: A modified golden ratio 2D radial Turbo-FLASH with CAIPI sequence was applied for the myocardial perfusion data acquisition and the acquisition diagram is shown in Figure 1. A CAIPI factor of two was used, so that 6 slices were grouped into 3 pairs. The dual-band excitation with the same phase was first applied interleaved for the 3 pairs of slices at the same angle ray, and dual-band excitation with different phases (0, π) was then done for the same 3 pairs of slices, as in Fig. 1. The sequence was performed on a Siemens 3T Trio whole-body scanner (Siemens Medical Systems, Erlangen, Germany). The acquisition matrix kx-ky-slice = 144 x144 x 6, and 200 temporal frames were acquired. The effective TR was tripled by interleaving the readouts, which yielded TR/TE = 9.7/1.5 msec. Other acquisition parameters were FOV = 280 mm^2, slice thickness = 8mm, distance between slices 2.4 mm, bandwidth = 1389 Hz/pixel, and flip angle = 30 degrees. The interleaved ungated CAIPI sequence was tested in vivo on three human subjects using a 32-channel cardiac coil and contrast injection. Image reconstruction for all of the datasets was performed with an adapted sensitivity encoding (SENSE) based compressed sensing algorithm with total variation (TV) applied as the constraint term in both the temporal and spatial directions [8].

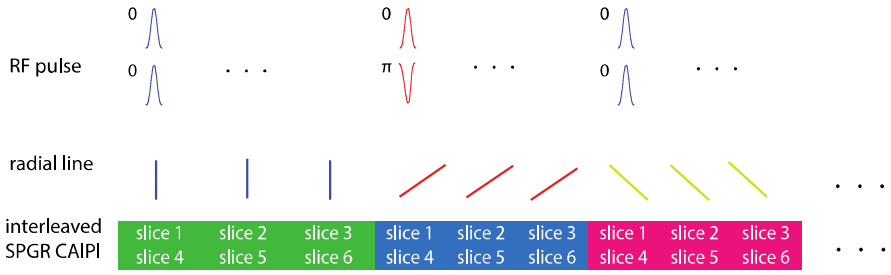

Figure 1: The acquisition pattern of ungated 6 slices interleaved golden ratio radial CAIPI sequence.

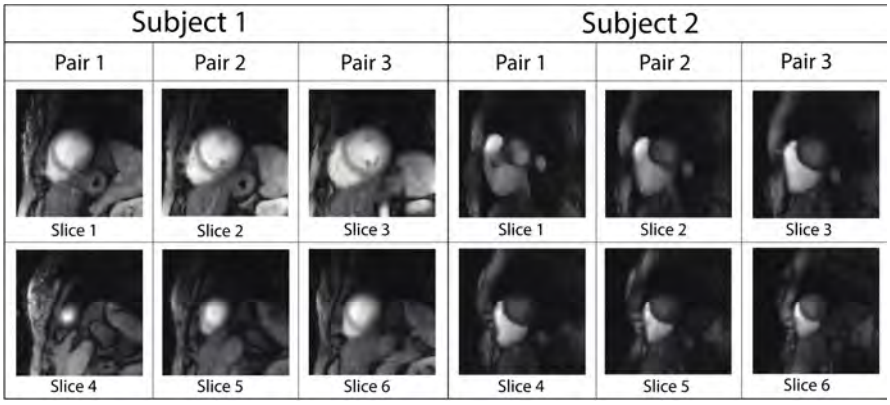

Figure 2: Two subjects with ungated 6 slice interleaved radial CAIPI acquisition. Each column shows slices that were acquired simultaneously.

RESULTS: Figure 2 shows the results from two human subjects (mid- and early contrast enhancement stages, respectively). Two slices were acquired simultaneously as a pair. The multi-slice method covers the whole heart. The contrast enhancement in the myocardial wall also could be clearly observed.

DISCUSSION: The combination of simultaneous multi-slice imaging with the interleaved SPGR sequence offers a different type of perfusion sequence. Benefits include robustness to arrhythmia, highly efficient acquisition (no time used for saturation pulses or saturation recovery), and the acquisition of multiple cardiac phases in a single slice (an advantage if temporal resolution is sufficient, and otherwise a possible disadvantage). A limitation could be if some or all of the slices go out of steady-state due to respiratory or cardiac motion. Since steady-state is re-achieved very rapidly in such cases, this may not be a concern. Slice profile at steady state and inter-slice effects could also influence image quality [9].

CONCLUSION: This work showed successful preliminary results of combining radial CAIPI with interleaved SPGR readouts. This approach enables rapid perfusion imaging with good spatial coverage of the left ventricle. Further work is needed to optimize the reconstruction algorithm and to evaluate the performance of the approach.

REFERENCES: [2] BL Gerber et al., JCMR 10:18, 2012. [3] E DiBella et al., MRM 67:609–613, 2012. [4] B Sharif et al., MRM 72:1620-1628, 2014. [5] B Sharif et al., ISMRM, p879, 2014. [6] H Wang et al., ISMRM, p3934, 2014. [7] Breuer et al., MRM 53:684-91, 2005. [8] G Adluru et al., ISMRM, p1532, 2014. [9] W Hänicke et al., JMR 77,64-74, 1988.