Highly accelerated 3D SSFP first-pass myocardial perfusion at 3T using a 32-channel coil

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Introduction: First-pass myocardial perfusion is usually carried out through a 2D multislice saturation recovery fast-gradient-echo pulse sequence. However, multislice acquisition suffers from substantial drawbacks such as slice misgregation and incomplete ventricle coverage. Three dimensional first-pass can overcome these drawbacks by providing full heart coverage while maintaining good image quality and signal to noise ratio [1-2]. In this work a new 3D Fiesta (also known as TrueFisp or balanced SSFP) perfusion sequence is presented. High acceleration factors are provided by 32-channel phased-array coil that enables good image resolution. This study was performed at 3Tesla were first-pass perfusion already showed better T1 contrast with respect to 1.5T [2-4].

Methods: In order to perform a myocardial saturation that was less sensitive to B1 field inhomogenieties as possible, an adiabatic BIR4 radio frequency pulse [4] was designed and applied before 3D-Fiesta acquisition. Fiesta was chosen since it has proved to provide both contrast-to-noise ratio (CNR) and Signal-to-noise ratio (SNR) with respect to Fast-spoiled gradient-echo and Echo-planar pulse sequences given its T2/T1 signal dependence [5-6]. Acquisition was performed with a Signa Excite 3 Tesla scanner (General Electric, Milwaukee, WS, USA) The acquisition parameters were: TR/TE=2.8ms/1.3ms, 128x96x10 acquisition matrix (2 slices were discarded after reconstruction to ensure good slab profile), flip angle(α)=45°, FOV=44x44cm, slice thickness=8mm. The steady state was approached by a α/2-TR/2 preparation followed by 10 dummy excitation pulses. 4-fold Asset acceleration in the in-plane phase encoding direction could be used thanks to the use of a 32 channel phased-array cardiac coil (Invivo, Orlando, FL, USA). Partial Fourier acquisition was also used (Nex=0.5) setting to 8 the number of additional in-plane phase encoding lines required for homodyne reconstruction. Thirty phases were acquired with each phase representing 2R-R intervals. Using this approach, in-plane phase encoding lines were acquired in an interleaved manner, odd and even lines in consecutive but different R-R intervals for each phase. After the saturation pulse and a time delay (TD) of 100ms, the acquisition always started from overscan lines to ensure that the delay time set at the scanner was as close as possible to the center of k-space. Overall, each heartbeat experienced a time acquisition window of 280ms in middle diastole and the time delay between the saturation pulse and the center of k-space was about 220ms. In order not to exceed SAR limits, the saturation BIR4 pulse length was stretched to 8ms. Three patients, already prescribed for delay enhanced examination, were scanned with 3D Fiesta perfusion after providing informed written consent. Contrast media (0.1 mmol/kg Gd-DTPA, Gadovist®; Bayer Schering Pharma; Berlin, Germany) was injected at a rate of 4 ml/s and subjects were instructed to hold their breath as long as possible. Short axis views were acquired covering the left ventricle from apical to basal levels. For a mid-basal slice, SNR, CNR and contrast enhancement ratio, CER=(peak-baseline)/baseline were calculated in four regions of interest (ROI) that included respectively the septal, lateral, inferior, and anterior regions.

Results: Figure1 shows example images for all 8 slices acquired during first pass perfusion for a randomly selected patient: (a) pre-contrast, (b) right ventricle (RV) enhanced, (c) left ventricle (LV) enhanced, and (d) myocardium enhanced. This patient, as well as the other two, was not found to be affected by any ischemic heart disease. Overall, for a mid-basal slice, pre-contrast myocardial SNR and CNR were respectively 15 and 12. Post-contrast analysis showed an SNR and CNR of 41 and 37, whereas CER was 3.3.

Figure 1: Example of multiphase 3D Fiesta first-pass perfusion using 128x96x8 image matrix for a subject with heart rate=85 heart beats per minute

Discussion and conclusions: 3D first pass perfusion with a SSFP pulse sequence was proved to be feasible at 3Tesla. The achievement of high acceleration factor was made possible by the use of the 32 channel cardiac coil. Good image quality, in terms of high SNR and CNR, was achieved in all patients. Although in some images Fiesta typical banding artefacts were seen in the inferolateral region during myocardium enhancement, they could be easily identified and were unlikely to affect the final medical evaluation. A comparison with a two-dimensional parallel imaging approach is under investigation to understand if it is possible to improve the temporal resolution (1 R-R per each phase) without losing too much in term of SNR and aliasing artefacts in the slice encoding direction.

References: [1] Kellman P *et al*, ISMRM 2004 [2] Shin T *et al*. ISMRM 2008. [3] Shin T *et al*, JCMRI 2008. [4] Sandman D N *et al*, ISMRM 2005. [5] Wang Y *et al*, MRM 2005. [6] Foo T *K et al*, ISMRM 2004.