3D Phase Sensitive IR Prepared Spoiled Gradient Echo Technique with Free Breathing Navigators – A Tool for Quantitative Characterization of Scar

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Introduction

Delayed myocardial enhancement (DE) imaging is a well-established method for the detection of scar and fibrosis.
Recent publications [1] have triggered the interest to quantify the amount, shape and border-zone of scar as potential prognostic parameters. As the enhancing lesions may show an irregular or diffuse appearance, a 3D technique would deliver user independent, reproducible image results with high spatial resolution needed for infarct quantification.
Previous work [2] has demonstrated the benefits of phase-sensitive inversion recovery (PSIR) methods that eliminates the necessity for precise selection of the inversion time (TI). So far only 2D and 3D breath hold techniques have been available using the phase sensitive approach [3,4] that are limited in spatial resolution (e.g. 5-8 mm slices) due to clinical acceptable breath hold times. Conventional 3D navigator based non-PSIR techniques have demonstrated potential to depict small lesions and even detect RF ablation patterns in the atrium [5]. The TI chosen at the start of imaging may result in sub optimal nulling of myocardium due to contrast washout during image acquisition.
This work demonstrates the feasibility to overcome the limitations described above, by implementing a navigator gated three-dimensional high resolution delayed enhancement technique utilizing a phase sensitive reconstruction achieving better than 2mm isotropic resolution.

Materials and Methods

Sequence Design (Siemens MAGNETOM Avanto and Espree)

- Segmented 3D-PSIR Turbo-FLASH sequence (Figure 1)
- PSIR reconstruction supporting parallel imaging (GRAPPA)
- Linear *k*-space reordering
- Respiratory synchronization for every other heartbeat [6] using crossed slices navigator
- Re-inversion at navigator's position to ensure a reliable navigator echo
- Typical parameters: TE/TR/TI = 3.3/6.8/280 ms (BW=295 Hz/pixel), TI = 280ms, FOV = 350x255x86mm, 192x140x48 matrix, α=20°, *k*-space lines per heartbeat = 35-40, GRAPPA acceleration factor 2

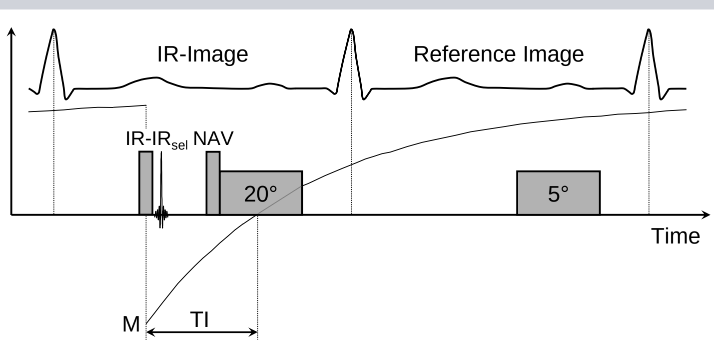

Figure 1: *Sequence Design. A segmented 3D Turbo-FLASH sequence is acquiring inversion recovery (IR) prepared image data (flip angle α = 20°) and reference data (5°) in separate heartbeats. Navigators echoes (NAV) synchronize the data acquisition with respiratory motion for every other heartbeat.*

Volunteer and Patient Study

- Volunteers and patients with chronic myocardial infarction (MI)
- Imaging 10-15 min post contrast injection ([Gd] = 0.15-0.2 mmol/kg, Magnevist, Schering AG, Berlin, Germany)
- Typical navigator acceptance window of 4mm
- Data acquisition during diastolic quiescent period
- Slice orientation transversal to simplify exam planning

Results

Volunteer Study

The data acquisition time for the 3D PSIR dataset covering the whole heart was 7-8.5min with a navigator efficiency of >60% for our volunteers showing a regular breathing pattern. The PSIR method provided excellent signal nulling of the normal myocardium despite the comparably long acquisition time and showed high contrast to- noise ratio between normal myocardium and blood pool. The (nearly) isotropic resolution (1.8x1.9x1.8 mm) allowed a multi-planar reformatting in arbitrary slice orientations (Fig. 2).

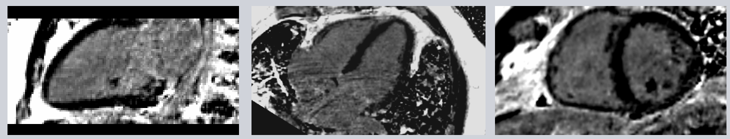

Figure 2: *Volunteer Study: Two chamber, four chamber and short axis PSIR images. These cardiac views have been reformatted from a 3D PSIR image data set acquired in the transversal orientation (1.8x1.9x1.8 mm).*

Patient Study

A 3D PSIR data set was acquired in a 73 years old female patient 9 months after myocardial infarction. The patient received a coronary artery bypass graft 5 months post MI. The achieved spatial resolution of (1.8x1.4x2 mm, acquisition time ~9min) allowed a multi-planar reconstruction of standard cardiac views (Fig. 3). The re-formatted images depicts sub-endocardial scar and an isolated septal lesion.

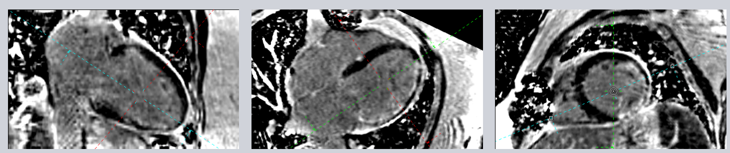

Figure 3: *Chronic infarct patient (9 months post MI): Two chamber, four chamber and short axis PSIR images. have been reformatted from a 3D PSIR image data set (1.8x1.4x2.0 mm voxel size) acquired in the transversal orientation. This dataset shows sub-endocardial scar and an isolated septal lesion in a case of chronic myocardial infarction.*

Discussion

We have demonstrated the extension of a 2D-PSIR technique to a navigator gated 3D PSIR sequence. The PSIR technique is of particular advantage in relatively lengthy navigator based 3D acquisitions, as a phase sensitive acquisition can compensate for inversion time changes during data collection and is intrinsically less sensitive to the correct choice of the inversion time. Excellent signal nulling of the myocardium is achieved despite the comparably long data acquisition time. Further reduction of scan time can be achieved by the application of higher parallel acquisition factors in phase and slice encoding direction. The use at higher field strength will allow even higher spatial resolution and can further reduce scan times. The 3D navigator based PSIR method provides a tool that potentially allows a more accurate and user independent quantitative scar characterization, e.g. of peri-infarct zones and enhancement patterns.

References

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