

3D Phase sensitive IR prepared spoiled gradient echo technique with free breathing navigators – a tool for quantitative characterization of scar

S. Zuehlsdorff¹, P. Kellman², Y. Chung¹, P. Weale¹, and R. Jerecic¹

¹MR Research and Development, Siemens Medical Solutions USA, Inc., Chicago, IL, United States, ²Laboratory of Cardiac Energetics, National Institutes of Health/NHLBI, Bethesda, MD, United States

Introduction

Delayed myocardial enhancement (DE) imaging is a well-established method for detection of scar and fibrosis, e.g. in ischemic and non-ischemic cardiomyopathies. Recent publications [1] have triggered a high interest in not only imaging the presence or absence of late enhancement but also to quantify the amount, shape and border zone of scar as potential prognostic parameters. As the enhancing lesions often show an irregular or diffuse appearance, a 3D technique that delivers user independent, reproducible image results with high spatial resolution would be desirable and is the goal of this work.

Previous work [2] has demonstrated the benefits of phase-sensitive inversion recovery (PSIR) methods. The consistence of contrast and appearance of hyper enhanced regions over a relatively large range of inversion recovery times (TI) reduce or even eliminate the necessity for precise selection of the correct TI to generate optimized contrast between myocardium and lesion and allow a user independent and reproducible imaging protocol. So far only 2D and 3D breath hold techniques have been available using the phase sensitive approach [3,4]. For quantitative characterization of scar both approaches have its limitations: 2D DE imaging is limited by partial volume effects due to the slice thickness that is typically chosen between 6-8 mm. 3D PSIR is limited in its spatial resolution by clinically 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]. But the choice of the correct inversion time remains a subjective parameter decided by the user; even if tools like TI scouting are used it is difficult to predict the contrast washout over such a lengthy acquisition, which will impact the image quality as well as accuracy and reproducibility of the quantitative analysis.

This work demonstrates the feasibility to overcome the limitations described above, by implementing a navigator gated three-dimensional high resolution DE technique utilizing a phase sensitive reconstruction. Images from healthy volunteers are presented demonstrating whole heart coverage, with isotropic resolution and scan times of about 8 min.

Material and Methods

Sequence Design: A segmented 3D-PSIR imaging sequence using a Turbo-FLASH readout module with a linear reordering scheme was implemented on a clinical 1.5T MRI scanner (Siemens MAGNETOM Avanto, Erlangen Germany). To achieve high spatial resolution, a navigator pulse using the crossed slice approach was added. The navigator synchronizes the respiratory motion with data acquisition for every other heart beat. The variation in slice positions between the IR prepared and the reference image due to respiratory motion has been shown to be negligible, as the reference image is a low-resolution phase estimation required for PSIR reconstruction [6]. A slice selective re-inversion pulse at the navigator's slice position was applied to ensure a reliable navigator echo signal follows the non-selective IR-pulse.

Volunteer Study: Ten minutes after administration of a Gd-based contrast agent (0.15 mmol/kg, Magnevist, Schering AG, Berlin, Germany) the navigator gated 3D PSIR sequence was applied to consented healthy volunteers using the following imaging parameters resulting in nearly isotropic image resolution of 1.8 mm x 1.9 mm x 1.8 mm voxel size: TE/TR = 3.3ms/6.8ms (BW=285Hz/pixel), TI = 280ms, FOV = 350x 255 x 86mm, matrix size = 192x140x48, flip angle = 20deg, acquisition of 35-40 k-space lines per heartbeat. A navigator window of 4 mm was selected and data acquisition was timed to the diastolic quiescent period of the cardiac cycle.

The prescription of a transaxial oriented volume was chosen to further simplify and speed up the exam planning, as the standard cardiac views could be reconstructed retrospectively from the acquired isotropic 3D volume.

Results

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 shows high contrast-to-noise ratio between normal myocardium and blood pool. The isotropic resolution allowed a multi-planar reformatting in arbitrary slice orientations (Fig. 1).

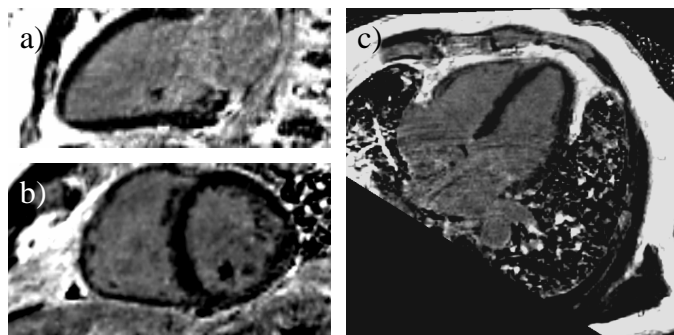


Figure 1: Multi-planar reconstructed delayed enhancement images utilizing 3D PSIR in a healthy volunteer. The nearly isotropic resolution (1.8x1.9x1.8mm) of the raw images acquired in axial orientation translated in to a comparable voxel size for (a) 2-chamber view, (b) short axis views and (c) 4-chamber view. Normal myocardium shows excellent signal suppression.

Discussion

We have demonstrated that the approach of a 2D-PSIR technique can be successfully extended to a navigator gated 3D PSIR sequence. The PSIR technique is of special advantage in navigator based 3D acquisitions, as a phase sensitive acquisition can compensate for inversion time changes during data acquisition and is intrinsically less sensitive to the correct choice of the inversion time. Therefore excellent signal nulling of the myocardium could be achieved despite the comparably long data acquisition time, as demonstrated in this volunteer study. As the images provide sufficient SNR, a further reduction of scan time can be achieved by the application of parallel acquisition techniques in phase and slice encoding direction. The use at higher field strength such as 3T will allow even higher spatial resolution and can further reduce scan times

In this study, the acceptance rate of the navigator echo was typically very high. However, in patients an average acceptance rate of of <40% is observed using conventional navigator techniques. Uses of motion adaptive navigator approaches that compensate for drifts in the respiratory pattern would further increase scan efficiency. 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. Patient studies will follow to demonstrate this potential.

References

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