Three Dimensional Phase Sensitive Inversion Recovery (PSIR) TurboFLASH for Evaluation of Left Ventricular Myocardial Scar

A. Kino[1], J. Sheehan[1], S. Zuehlsdorff[2], P. Weale[2], X. Liu[1], R. Ramsey[1], R. Jerecic[2], and J. Carr[1]

[1]Radiology, Northwestern University, Chicago, IL, United States, [2]MR Research and Development, Siemens Medical Solutions, Chicago, IL, United States

Delayed enhanced (DE) imaging is a well-established method for detection of myocardial scar. Recent publications [1] have triggered high interest in not only imaging the presence or absence of late enhancement but also quantifying the amount, shape and border zone of scar as potential prognostic parameters. Furthermore, atypical scars such as occur in cardiomyopathies and myocarditis, are increasingly being primarily evaluated with MRI. As such enhancing lesions are often small and show an irregular or diffuse appearance, a 3D-imaging strategy would be more desirable so that the entire heart can be covered in a single acquisition. 2D PSIR TurboFLASH is a widely accepted viability imaging technique having the advantage of being independent of inversion time (TI) thus making such protocols easy to use and reproducible [2]. 3D viability strategies, incorporating respiratory gating, have been shown to detect small myocardial scars compared to 2D approaches. The TI, however, can change substantially during the scan period and result in a reduction in image quality, especially when a conventional magnitude reconstruction algorithm is utilized. When phase sensitive reconstruction is combined with the 3D whole heart approach, the TI should remain constant thereby producing more consistent image quality. The purpose of this study was to assess a 3D PSIR TurboFLASH imaging technique for detecting left ventricular myocardial scar and compare it to a conventional 2D PSIR TurboFLASH.

MATERIAL AND METHODS

Sequence Design: A segmented 3D-PSIR imaging sequence was implemented on a clinical 1.5T MRI scanner (MAGNETOM Avanto, Siemens AG Medical Solutions, Erlangen, Germany) as described in [3] and represented in Figure 1.

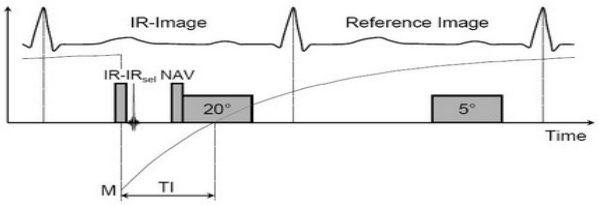

***Figure 1**: Sequence Design. A segmented 3D Turbo-FLASH sequence is acquiring inversion recovery (IR) prepared image data (flip angle α 20°) and reference data(5°) in separate heartbeats. Navigators echoes (NAV) synchronize the data acquisition with respiratory motion for every other heartbeat.*

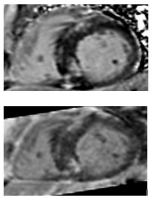

***Figure 2** demonstrates reformatted 3D PSIR short axis image (bottom), matching to the 2D PSIR images (top).*

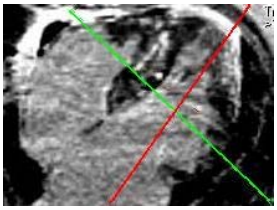

***Figure 3** shows 3D PSIR images of a patient with Hypertrophic obstructive cardiomyopathy presenting multifocal patchy delayed enhanced lesions within the hypertrophic thickened myocardium.*

Patient Study: Twenty two patients with clinically suspected myocardial scarring were scanned ten to fifteen minutes after contrast injection (0.15 mmol/kg, Magnevist, Schering AG, Berlin, Germany) using an established breath-hold 2D PSIR protocol, where a stack of segmented breath-hold 2D-PSIR images are acquired covering the left ventricle from base to apex (6 mm slice thickness with 4 mm gap). Subsequently, the navigator-gated 3D PSIR sequence was implemented using the following imaging parameters: TE: 1.7 ms, TR: 700ms, TI: 300 ms, flip angle =20°, FOV =350x255x86mm, matrix size = 192x132x48, acquisition of 35-40 *k*-space lines per heartbeat. Near isotropic spatial resolution of 1.8 mm x 1.9 mm x 1.8 mm voxel size was achieved. A navigator window of 4 mm was selected and data acquisition was timed to the quiescent diastolic 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.

Evaluation:

The 3D-PSIR images were reformatted in twenty short-axis data matching the slice orientation of the 2D-PSIR data from the base to apex of the left ventricle. Due to the thinner slice thickness of the 3D-PSIR data a stack of three 2 mm slices was reconstructed to match the coverage of a 2D slice (Figure 2).

Quantitative: Regions of interest (ROI) were drawn around enhanced regions on both 2D and 3D images and the volume of scar per patients calculated. The results for 2D and 3D methods were compared using a student T test.

Qualitative: 2D and 3D images were evaluated independently by two readers using the AHA-16 segment model Image quality was scored on 1-4 Likert scale. Furthermore each segment was assessed for scar and scored based on percentage of scar per segment (0=no scar, 1= 25%, 2=50%, 3=75%, 4=100%). Location of scar within segment was also scored (1=subendocardial, 2=central, 3=subepicardial, 4=transmural). The scores for the 2D and 3D images were calculated and compared using a student's T test

RESULTS

The average acquisition time for 3D PSIR was 6 minutes with an average navigator efficiency of 34% and for 2D PSIR was 6 minutes for a total acquisition of 10 slices. 5 out of the 22 patients had a score of 0 for image quality and were therefore excluded from further analysis. Out of the 17 patients five had detectable scar in both 2D and 3D. Scar quantification in the reformatted 3D PSIR images demonstrated that there is no significant difference between the 2D and reformatted 3D PSIR images (p=0.4454) in areas where both methods detected scar. Qualitative analysis demonstrated that 2D PSIR presents better image quality compared to 3D PSIR (2D: 1.7 3D: 1.2 average value on Likert scale, p<0.001). Overall image score for location of scar were similar for 2D PSIR and 3D PSIR (average score 2D: 5.6, 3D: 6.0, p = 0.8) and also for percentage of scar per segment however with an average score for 2D: 5.1; 3D: 5.6 and p=0.7. The numbers of discrete enhanced lesions detected at 3D PSIR were 66 and at 2D PSIR were 47.

Discussion

Respiratory-gated 3D PSIR TurboFLASH is comparable to the 2D PSIR TurboFLASH gold standard for quantitative and qualitative assessment of left ventricular myocardial scar. The 3D PSIR technique detected more discrete lesions within the myocardium compared to the 2D approach. The 3D imaging strategy allows for complete heart coverage in a contiguous dataset so that even the smallest scars can be detected. Image quality may be impaired with 3D PSIR TurboFLASH in some patients due to breathing motion artifacts and inconsistent respiratory gating. Improved navigator schemes and shorter scan times will lead to overall improved image quality.

Refereneces

[1] Yan AT *et al.* Circulation 114: 32-39 (2006) [2] Kellman P *et al.* Magn Reson Med 47: 372-382 (2002) [3] Zuehlsdorff S, et al. Proc Intl Soc Mag Reson Med 2007; 14: 2530