A fast free-breathing 3D sequence for delayed enhancement imaging of the myocardium: Comparison with standard 2D breath-hold imaging

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INTRODUCTION Delayed enhancement MRI (DE-MRI) of the myocardium is a diagnostic standard for assessment of viable and infarcted myocardium due to its excellent tissue contrast and high spatial resolution (1). DE-MRI is commonly performed using an inversion recovery prepared 2D fast gradient recalled echo sequence, with multiple images acquired during repetitive breath-holds. This technique is limited in the achievable spatial resolution and requires significant patient cooperation. Breath-holding in cardiac patients also has the problems of substantial diaphragmatic drift during breath-holding in 33% of these patients (2) as well as slice misregistration, which can cause gaps between adjacent slices. Navigator gated 3D DE-MRI has been developed to address these problems (3), but clinical application has been limited in part due to long imaging time associated with respiratory drift. The objective of this study was to develop a rapid and accurate free-breathing 3D DE-MRI (3DNAV) sequence for dyspneic patients and to evaluate its utility in routine clinical imaging with breath-hold 2D DE-MRI (2DBH) as a reference standard.

MATERIALS AND METHODS

Compared to 2DBH, 3DNAV imaging provides higher spatial resolution, thinner slices, and contiguous coverage of the ventricles during free breathing. As illustrated in Fig.1, 2DBH imaging suffers from the slice gap problem due to the operator's choice (e.g., 6mm slice/4mm skip to reduce the number of breath-holds) or the inconsistent shifts of neighboring slices acquired in different breath-holds (slice misregistration). Therefore, 3DNAV may be better than 2DBH in the detection of small infarcts.

The implemented IR prepared 3DNAV sequence was based on the ECG-triggered navigator gated pulse sequence originally developed for coronary imaging (4,5). To reduce scan time, the sequence combined 3D partial k-space acquisition with a highly efficient 2-bin phase-ordered automatic window selection (PAWS) navigator gating algorithm. This algorithm automatically selects a gating window at the most likely diaphragmatic position even in the case of respiratory drift and reduces residual motion artifacts within the gating window (6).

The 3DNAV sequence was incorporated into a routine cardiac MRI protocol on a 1.5T GE clinical MR scanner. DE-MRI was initiated 10 min after contrast injection (0.2 mmol/kg), starting with serial 2DBH and followed by 3DNAV. Imaging was performed in 21 cardiac patients (9 male, mean age = 51 ± 20 years) using the following typical imaging parameters: 1) 2DBH: TR/TE/FA/rBW = 7.0 ms/3.4 ms/20°/±31.25 kHz, FOV = 36x27 cm^2, 256x192 matrix, slice = 6 mm/4 mm skip, 24 views per segment, 2RR, 2) 3DNAV: TR/TE/FA/rBW = 4.8 ms/1.5 ms/20°/±62.5 kHz, FOV = 36x27 cm^2, 256x256 matrix, slice = 5 mm, partial NEX = 0.75, partial kz factor = 0.75, 36 views per segment, 1RR. A custom navigator gating program was developed to control data sampling in real time using a gating window of 4 mm. Comparison of 2DBH and 3DNAV techniques was performed by two readers using three criteria: 1) image quality score (1=poor, 2=fair, 3=good, 4=excellent), 2) diagnostic findings (same/different), 3) favored technique (more confident diagnostic interpretation) in the case of same findings. In patients with hyperenhancement, infarct SNR (SNR_{inf}) and infarct-viable myocardium CNR ($CNR_{inf-myo}$) were also calculated.

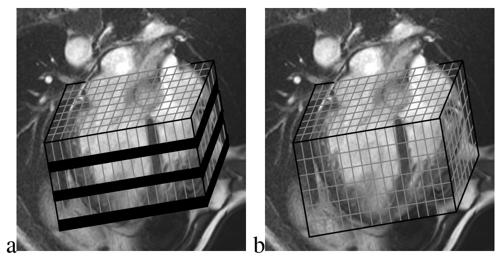

Fig.1.Illustration of spatial resolution and coverage of a) 2DBH and b) 3DNAV DE-MRI. Note the black slice gaps in 2DBH.

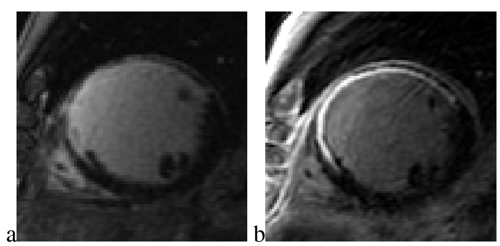

Fig.2. DE-MRI acquired with a) 2DBH and b) 3DNAV. 3DNAV provides substantially better delineation of infarct.

	Score (n=19)	Scan time (n=19)	SNR_{inf} (n=5)	$CNR_{inf-myo}$ (n=5)
2DBH	3.4 ± 0.8	415 ± 133 s	19 ± 7	12 ± 8
3DNAV	3.6 ± 0.7	247 ± 84 s	39 ± 18	28 ± 20
p	0.2	<0.0001	0.02	0.03

Table 1. Comparison of 2DBH and 3DNAV DE-MRI.

RESULTS

3DNAV imaging was completed succesfully in all subjects except two (one due to extremely poor cardiac gating and one because of real time navigating software problem). Myocardial hyperenhancement was observed in five subjects. Fig.2 shows a short axis image acquired in a 58-year-old patient with a known myocardial infarction in whom DE-MRI demonstrated hyperennancement within the anterior wall, anteroseptum, and anterolateral wall. The 3DNAV image provides higher SNR and CNR and much improved delineation of the infarct than than the 2DBH image. Table 1 summarizes the comparison between 2DBH and 3DNAV techniques. Overall 3DNAV provided slightly better image quality in 41% less time compared to 2DBH (the average navigator efficiency was 43 ± 12%). 3DNAV and 2DBH provided same diagnostic findings in 16 patients. Comparison by clinical readers indicated 3DNAV as a preferred technique in 11 of these patients. In general, 3DNAV was superior to 2DBH with regard to SNR and CNR, spatial resolution, and contiguous coverage of the ventricle.

CONCLUSION In patients referred for DE-MRI viability assessment, these data demonstrate a new navigator gated 3D technique which provides improved image quality, higher spatial resolution, and similar diagnostic value in approximately half scan time compared to the standard breath-hold 2D imaging. The 3D acquisition has the potential for more accurate quantification of scarred tissues. The developed sequence can be further optimized by increasing the spatial resolution and improving the infarct-blood contrast with blood suppression.

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