Clinical Value of a Single Breath-hold 3D Delayed Hyperenhancement Cardiac MRI with Sensitivity Encoding

A. S. Pednekar[1], S. Eder[2], A. R. Bhandiwad[2], and R. L. Eisner[2]

[1]Philips Medical Systems, Bothell, WA, United States, [2]Cardiac MR Imaging, Crawford Long Hospital, Atlanta, GA, United States

Abstract: Single breath-hold acquisition of the entire left ventricle would be of considerable benefit in patients having difficulty performing successive multiple breath-holds as well as in patients with variable heart rate. We developed an optimized 12-heart beat, single breath-hold, 3D myocardial delayed hyperenhancement sequence. On 18 patients evaluated for myocardial disease processes the new sequence yielded excellent diagnostic image quality. The CNR was comparable to that obtained with the conventional multiple breath-hold sequence. This 3D sequence further allowed fast acquisition of multi-slice images in different orientations to verify and evaluate the location and extent of nonviable myocardium or the presence of clot accurately.

Introduction: In current clinical practice a multiple breath-holds 2D ECG-gated inversion recovery (IR) prepared, fast segmented gradient recalled echo (GRE) sequence is the sequence of choice for the visualization of nonviable myocardial tissue through delayed hyperenhancement (DHE). However, the long acquisition time of this sequence leads to: 1) increased examination time; 2) patient discomfort; 3) limited coverage; 4) artifacts due to motion and varying time of inversion (TI) for patients with variable heart rate; and 5) effects of varying myocardial T1 relaxation time due to decrease in contrast medium over time. Recent studies using balanced steady state free precession (25-heartbeats) [1], variable sampling in time (24heartbeats) [2] and Sensitivity Encoding (SENSE) imaging (22heartbeats) [3] have demonstrated clinical promise. The purpose of this paper is to present a 12-heart beats 3D ECG-gated IR, fast GRE sequence using SENSE and to evaluate its diagnostic value in clinical practice in comparison to the conventional multiple breath-hold technique.

Materials and Methods: Studies were performed on 18 (9 males) clinical patients, with a mean age of 55 (range 17-78 years), 5 with areas of irreversible myocardial injury. Imaging was done on a 1.5T, Philips Intera clinical scanner, using a 5-element phased-array surface coil using vector-cardiographic (VCG) gating. The 2D IR images (GRE, 40 k-space lines per R-R, TR/TE/flip: 3.9 msec/1.25 msec/15 deg; acquired spatial resolution: 1.7 x 2 x 8 mm^3) were acquired 12 to 15 minutes after contrast injection in the following order: a series of 10 to 13 contiguous short-axis (SA) slices covering the entire LV from apex to base (the level of the mitral valve annulus), a vertical long-axis (VLA) view, a 4-chamber (4CH) view. Each slice was acquired during suspended respiration (10-12 heartbeats). The 12 heart beat, single breath-hold 3D IR images (GRE, 40 k-space lines per R-R, TR/TE/flip: 6 msec/2.9 msec/15 deg; acquired spatial resolution: 1.37 x 1.95 x 16 mm^3) were acquired immediately after 2D IR acquisition. The 3D sequence uses SENSE in phase (factor 1.8) and slice (factor 1.5) directions with phase encodings for each slice measured in consecutive shots in linear order of k-space lines. Fourier interpolation was used to reconstruct slices of 8 mm thickness. The TI was determined using a Look-Locker sequence before 2D IR SA acquisition and was increased by 20 msec for subsequent acquisitions in other imaging planes. The techniques were quantitatively evaluated for the signal-to-Noise Ratio (SNR) and Contrast-to-Noise Ratio (CNR) by drawing regions of interest inside the blood pool (Bl), normal myocardium (Myo), and injured myocardium (Imyo).

	Bl SNR	Myo SNR	Imyo SNR
2D IR	13.36 ± 3.62	1.03 ± 0.35	5.95 ± 1.0
3D IR	17.35 ± 5.82	4.1 ± 2.57	9.01 ± 1.67
p-value	< 0.02	< 0.0001	< 0.01

Table 1: SNR for 2D and 3D DHE sequences

	Bl-Myo CNR	Imyo-Myo CNR	Imyo-Bl CNR
2D IR	17.27 ± 8.91	21.5 ± 6.49	6.59 ± 6.24
3D IR	14.94 ± 8.91	15.26 ± 6.34	4.41 ± 6.44
p-value	NS	NS	NS

Table 2: CNR for 2D and 3D DHE sequences.

Results: A representative comparison of SA images in identical locations is shown in Fig. 1. The additional single breath-hold VLA stack was acquired for verification of the extent of the infarct and clot. There was a significant increase in blood ($p<0.01$), myocardium ($p<0.0001$), and injured myocardium ($p<0.01$) SNR from 2D to 3D technique (Table 1); while for Bl-Myo, Inj-Myo, and Inj-Bl CNR, the differences between 2D and 3D techniques were not significant (Table 2).

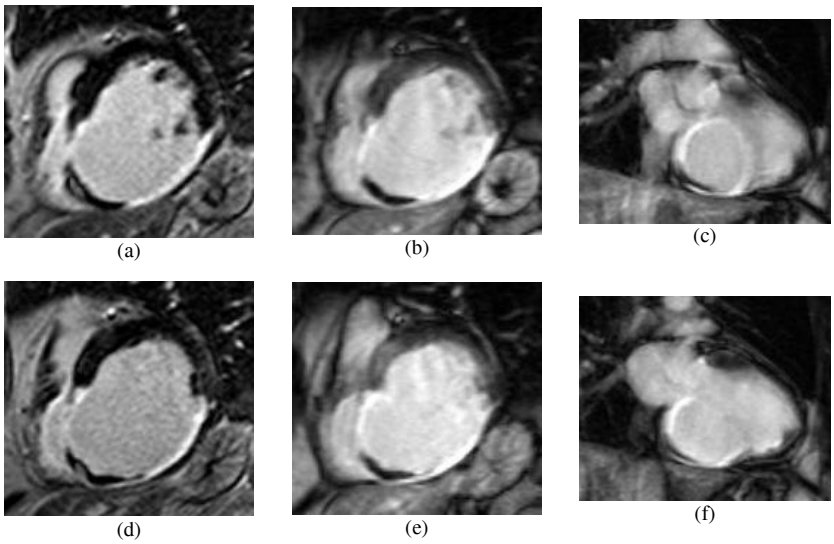

Figure 1: Short-axis images acquired using (a, d) 2D IR multiple breath-hold; and (b, e) 3D IR single breath-hold sequences; and VLA images acquired with 3D IR single breath-hold sequence.

Discussion: The single breath-hold 3D DHE acquisition with SENSE is feasible in clinical practice. Compared to the conventional multiple breath-hold sequence, the 3D sequence provides equivalent contrast between injured and normal myocardium and between myocardium and blood. In addition, the3D sequence provides significantly better SNR for all the tissues of interest. The 3D sequence has acceleration factor of 10 times for data acquisition in addition to time saved between breath-holds. As a complement to the higher spatial resolution 2D acquisition this very fast sequence can be used to 1) validate the findings of the 2D sequence; 2) reduce image artifactsusceptibility to fast and variable heart rate; 3) acquire diagnostic quality DHE images in patients unable to perform a succession of breath-holds; and 4) acquire additional corroborative multi-planar views.

Conclusion: The high signal intensity of 3D along with the faster acquisition with SENSE shows promise in clinical practice in terms of ability to acquire: 1) diagnostic quality delayed hyperenhancement images for patients having difficulty holding their breath or having variable heart rate; and 2) multi-plane, multi-orientation images to evaluate accurately the location and extent of irreversibly injured myocardium or presence of clot.

References: 1. M. Dewey et al: Radiology 2006; Vol. 239 (3): 703-709. 2. T.K.F. Foo et al: Radiology 2004; Vol. 230 (3): 845-851. 3. K. Gupta et al: JCMR 2002;Vol. 4 (1): 157.