Fast three-dimensional Assessment of Delayed Enhancement MRI in a single breathhold: Comparison with the conventional Two - Dimensional technique

V. V. Lenge[1], R. Agarwal[2], R. Muthupillai[3,4], B. Lambert[3], D. Dees[3], B. Cheong[1,3], and S. D. Flamm[2,3]

[1]Radiology, Baylor College of Medicine, Houston, Texas, United States, [2]Radiology, Cleveland Clinic, Cleveland, Ohio, United States, [3]Radiology, St. Luke's Episcopal Hospital, Houston, Texas, United States, [4]2Philips Medical Systems, Cleveland, Ohio, United States

Introduction:

Recent studies have shown that the so-called delayed enhancement MRI (DE-MRI) can identify irreversible injury with exquisite spatial and contrast resolution[1]. As originally described, the DE-MRI technique used a cardiac gated, inversion-recovery prepared segmented gradient echo method that collects one slice at a time. Therefore, the assessment of scar burden in the entire LV required a series of breathholds, and was a time consuming, and labor-intensive process. More importantly, the breath-holding time as well as the time required by the patient to recover between the breath-holds can add as much 7-9 minutes to complete an entire stack of slices covering the LV. A single breath-hold volumetric delayed enhancement imaging technique would address many of the issues associated with the 2-D DE technique. In this regard, *Pruessmann et al.* have developed a volumetric DE method that covers the entire LV in a single breath-hold using Sensitivity Encoded (SENSE) parallel imaging technique[2]. The purpose of this prospective study is to directly compare the performance of the 2D and 3D DE techniques with qualitative and quantitative approach for detection of delayed-hyperenhancement, in patients with angiographically documented chronic coronary artery disease.

Materials and Methods:

Patient population: Twenty patients (19 men; age range, 44-79 years, mean age, 61 years ± 10 years), with history of clinically proven chronic myocardial infarction were prospectively included in the study. All patients provided written informed consent.

Data Acquisition: All images were acquired on a Philips 1.5T imager with VCG gating, and a five-element synergy cardiac coil was used for signal reception. 2D DE Acquisition: The 2D-DE acquisition was a VCG gated, inversion-recovery prepared, segmented gradient echo acquisition with the following acquisition parameters: field-of-view: 384 x 384 mm; matrix size: 256 x 256; acquired voxel size: 1.5 x 1.5 x 10 mm; 32 phase encoding steps per RR interval; TR/TE/flip: 4.6/1.9/15°; NSA: 2; acquisition time per slice: 16 RR intervals. The inversion delay time (TI) between the inversion pulse and the beginning of the data acquisition necessary to null the signal from normal myocardium was determined by the Look-Locker sequence[3]. A centric phase encode ordering scheme was used for data collection to capture the maximally contrast when the myocardial signal is fully nulled. The data acquisition was timed to occur in diastole to minimize cardiac motion. On average, 10 slices were obtained in the short axis. Depending on the heart rate, the time it took to acquire the whole stack of short-axis images ranged from 5 to 8 minutes (16 heartbeats per breath hold per slice). 3D DE Acquisition: A single volumetric slab consisting of 10 short axis slices was prescribed to cover the entire LV. Analogous to the 2D-DE technique, the 3D-DE technique was an inversion recovery prepared, VCG gated, segmented gradient echo sequence. The parameters of the 3D volumetric acquisition were as follows: field-of-view: 384 x 384 mm; matrix size: 240 x 198; acquired voxel size: 1.8 x 1.8 x 10 mm; 48 phase encoding steps per RR interval; TR/TE/flip: 4.6/1.9/15°; NSA: 1; acquisition time per slice: 24 RR intervals. A SENSE acceleration factor of 2.0 was used along the in-plane phase encoding direction to reduce the number of phase encoding steps by a factor of two. The total breath-hold time was 24 heartbeats for the entire acquisition that included the over sampling requirements along the slice select direction. A two-dimensional centric phase encoding order that sampled the center of k-space in the k_y-k_z plane was used for data collection.

Data Analysis: The total myocardium volume, hyperenhancement volume and percentage of scar relating to the whole myocardium were determined by both techniques, as well as, the contrast to noise (CNR) and signal to noise (SNR) ratios between delayed enhancement and normal myocardium, and between delayed enhancement and blood pool. Detection of presence and extent of DE was also assessed. Paired T Test and Bland Altman were used for statistical analysis.

Results: There was no statistically significant difference between the 2D-DE technique and the 3D-DE technique for the measurement for either the total myocardial volume (153.5 ± 33 cm^3 for 2D vs. 144. ± 39 cm^3 for 3D, P=NS), or irreversibly injured myocardial volume (31.8 ± 23.7 cm3 vs. 31.0 ± 16.2 cm^3). Mean CNR and SNR for enhanced-myocardium vs. normal myocardium, was significantly higher for 3D technique compare to the 2D sequence (CNR: 30.9 ± 39.2 vs. 11.6 ± 8.7, p=0.04; SNR: 35.5 ± 44.4 vs. 13.0 ± 9.3, $p<0.05$) (Table 1), with good inter and intra-observer agreement. A total of 340 segments from 20 patients were analyzed in a qualitative approach with excellent agreement for detecting the presence of irreversible injury in any given segment ($K = 0.86$), in addition to the extent of the DE (grade I-II: <50% injury, K: 0.77, grade III: 51-75% injury, K: 0.62, IV: 76-100% injury, K: 0.83) between both techniques (Table 2).

Table 1: CNR and SNR in 2D and 3D-DE techniques

	2D-DE	*3D-DE*	*P-value*
CNR DE/NL	*11.6*	*30.9*	*0.04*
CNR DE/BP	*0.2*	*-0.1*	*PNS*
SNR	*13*	*35.5*	*0.03*

Conclusions: Despite a dramatic reduction in scan time, the total myocardial volume and irreversibly injured myocardial volume estimated by the 2D-DE and 3D-DE techniques are in good agreement. The SNR and the CNR between irreversibly injured myocardium and normal myocardium of the 3D DE technique was significantly better than the 2D DE sequence.

Table 2: Agreement between 2D and 3D-DE sequences for the extent of DE

3D *N = 340*	*0*	*I-II*	*III*	*IV*
2D *0*	***179***	*11*	*0*	*1*
I-II	*11*	***92***	*4*	*1*
III	*0*	*3*	***11***	*4*
IV	*0*	*1*	*0*	***22***

References:

1. *Kim RJ, Fieno DS, Parrish TB, Harris K, Chen EL, Simonetti O, Bundy J, Finn JP, Klocke FJ, Judd RM. Relationship of MRI delayed contrast enhancement to irreversible injury, infarct age, and contractile function. Circulation. 1999;100:1992-2002.*
2. *Pruessmann KP, Weiger M, Scheidegger MB, Boesiger P. SENSE: sensitivity encoding for fast MRI. Magn Reson Med. 1999;42:952-62.*
3. *Locker DC, Look DR. Time saving in measurement of NMR and EPR relaxation times. Rev. Sci. Instrum. 1970;41:pp. 250-251.*