

Evaluation of Highly-Accelerated Non-Gated Cardiac Cine MRI in Tachycardia

Elwin Clark Bassett¹, Edward V. R. DiBella^{2,3}, Eugene Kholmovski^{2,3}, Brent Donald Wilson³, Christopher McGann³, Nassir F Marrouche^{3,4}, and Daniel Kim^{2,3}

¹Physics, University of Utah, Salt Lake City, Utah, United States, ²UCAIR, University of Utah, Salt Lake City, Utah, United States, ³CARMA, University of Utah, Salt Lake City, Utah, United States, ⁴Internal Medicine, University of Utah, Salt Lake City, Utah, United States

Purpose: The current gold standard for imaging left ventricular (LV) function is electrocardiogram (ECG) gated breath-hold (BH) cine MRI with balanced steady-state of free precession (b-SSFP) imaging [1, 2], which provides excellent myocardium-to-blood contrast. However, it yields non-diagnostic quality images in patients with arrhythmias because data acquisition is synchronized to cardiac rhythm and spread over multiple heart beats (i.e., irregular rhythm will cause different segments of cine data to be out of sync and cause image artifacts). We have developed an 8-fold accelerated non-gated cardiac cine sequence using k-t SPARSE-SENSE [3,4], which is a combination of compressed sensing [5] and SENSE [6]. The purpose of this study is to evaluate this pulse sequence for assessment of cardiac function in the context of tachycardia, where high temporal resolution is critically important for diagnostic confidence.

Methods: For pulse sequence and k-t SPARSE-SENSE implementation details, see reference [4]. Our research group is conducting a longitudinal study of large animals (dogs and goats) with chronic atrial fibrillation (AF) to study the relationship between AF and myocardial fibrosis. Our experimental dogs and goats have heart rates on the order of 110 beats-per-minute (bpm), which is considered to be tachycardia in patients. For each dog or goat, MRI examination is conducted after cardioversion (i.e., sinus rhythm). Our animals have different degrees of LV dysfunction, with LV ejection fraction (LVEF) ranging from 20-70%. As such, this experimental setting enables us to perform rigorous tests to evaluate the relative accuracy and precision of our non-gated cine MRI for quantification of LV function in tachycardia, compared with BH cine MRI. We imaged 12 animals (7 dogs, 5 goats) on a 3T system (Siemens Tim Trio, Siemens Verio). We performed BH cine MRI via a respirator, and our 8-fold accelerated non-gated cine MRI and standard (3-fold with TGRAPPA) non-gated cine MRI under free breathing. All three pulse sequences used field of view = 260 mm x 260 mm, slice thickness = 7 mm (with zero gap), flip angle = 40°. Other relevant imaging parameters are summarized in Table 1. The pulse sequence order was randomized to minimize the impact of physiological variation on LV function (e.g., anesthesia). Cine images were analyzed in the Argus software (Siemens) to calculate LVEF.

Results: Figure 1 shows representative BH cine, standard non-gated cine, and accelerated non-gated cine images of a goat. The mean heart rate of 12 animals was 105 ± 11 bpm. The mean LVEF yielded by BH cine, standard non-gated cine, and accelerated non-gated cine is summarized in Table 1. The normalized root-mean-square error was 8.5 and 3.1% for standard and accelerated non-gated cine, respectively. Figure 2 shows the Bland-Altman results. Compared with BH cine, accelerated non-gated cine was in good agreement (mean difference = 2.4 %, 95% confidence intervals at ± 3.0%), better than standard non-gated cine (mean difference = 6.5%, 95% confidence intervals at ± 10.5%).

Conclusions: Our study shows that our 8-fold accelerated non-gated cine MRI yields relatively accurate LVEF measurements in tachycardia, better than standard non-gated cine MRI. More work is needed to evaluate the diagnostic accuracy, precision, and confidence in patients in tachycardia.

References: [1]. Carr JC, et al. Radiology 2001; 219:828-34. [2]. Task Force of the European Society of Cardiology. Eur Heart J 1998; 19(1): 19-39. [3]. Otazo R, et al. MRM 2010; 64:767-776. [4]. Feng L, et al. Magn Reson Med. 2012 Aug 6 (DOI 10.1002/mrm.24440) [5]. Lustig M, et al. MRM 2007;58:1182-1195. [6]. Pruessman KP, et al. MRM 1999; 42:952-62.

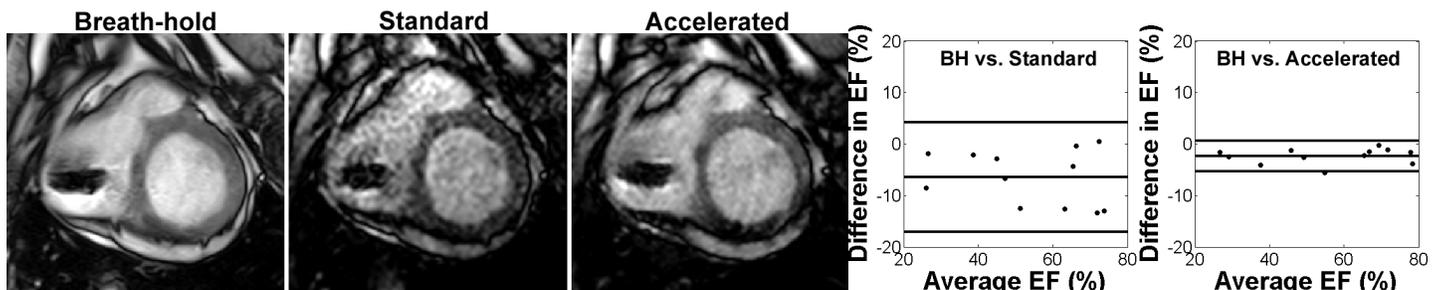


Figure 1: Short-axis images acquired using (left) breath-hold cine, (middle) standard non-gated cine, (right) 8-fold accelerated non-gated cine. **Figure 2:** Bland-Altman analysis results between (left) BH vs. standard non-gated and (right) BH vs. accelerated cine.

	BH	Standard	Accelerated
Matrix Size	192 x 192	128 x 128	128 x 128
Temporal Resolution	21 ms	126 ms	47 ms
Mean LVEF	57 ± 17%	51 ± 16%	55 ± 18%

Table 1: Image acquisition Matrix Size, Temporal Resolution, and Mean LVEF for different pulse sequences.