Synthetic LGE Derived Automatically from Cardiac T_1 Mapping Using k-means clustering of T_1: virtual TI scout approach

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Introduction: Late gadolinium enhanced (LGE)[1] is the gold standard test for focal myocardial fibrosis. Cardiac T1 and extracellular volume fraction mapping acquisitions are emerging as promising methods for assessment of diffuse myocardial fibrosis [2]. We showed that LGE images can be synthesized from post-contrast cardiac T1 maps based on the Bloch equation describing inversion recovery [3]. Our prior work required manual calculation of myocardial T1 to define an inversion time (TI) to null the normal myocardium. In this study, we sought to extend this application by automatically generating several synthetic LGE images based on k-means clustering [4] of T1 values (i.e., virtual TI scout), in order to then visually determine the best TI value that nulls the normal myocardium, similar to how cardiac imagers determine the best TI value from a TI scout acquisition.

Methods: *(Animal Experiment)* We imaged five mongrel dogs with multiple RF ablation lesions on a 3T MRI system (Verio, Siemens) during equilibrium of Gd-BOPTA (slow infusion at 0.002 mmol/kg/min), using arrhythmia-insensitive-rapid (AIR) cardiac T1 mapping [5], standard LGE MRI, and 3D LGE MRI as the reference for scar detection. We note that our study was an add-on to an on-going canine MRI study aimed to characterize RF ablation lesions. Both cardiac T1 mapping and 2D LGE MRI acquisitions used identical spatial resolution = 1.4 mm x 1.4 mm x 7.0 mm, and 3D LGE was acquired with spatial resolution = 1.25 mm x 1.25 mm x 2.5 mm. *(Synthetic LGE)* After calculation of AIR T1 maps [4], we generated seven synthetic LGE images automatically using k-means clustering [4], with minimum and maximum limits defined as 200 and 1000 ms, respectively, based on the expected myocardial and blood T1 values following administration of contrast agent. For each k-means cluster T1, synthetic LGE image was derived using the Bloch equation describing an ideal inversion recovery: $M_z = 1 - 2 \times exp(-TI/T_1)$, where $TI = ln2 \times T_{1,cluster}$, where Mz is the longitudinal magnetization and equilibrium magnetization=1. We then visually selected the best TI value that nulls the normal myocardium (see Figure 1), where typically it is the 4th or 5th image. *(Image Analysis)* For qualitative image analysis, three radiologists independently scored the image quality (5-1: best-worst) and noise (5-1: least-most; ≥ 3.0 acceptable), where the readers were blinded to pulse sequence type and animal identity. For evaluation of the accuracy in scar detection, using 3D LGE MRI as the reference, three readers identified the scars in the left ventricle.

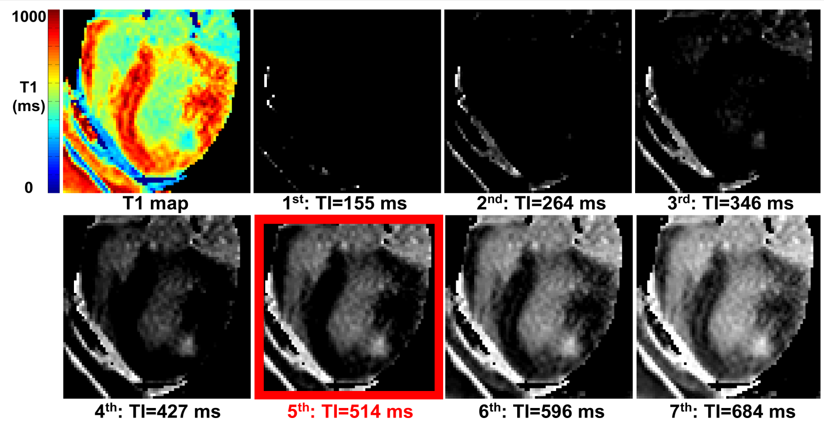

Figure 1. Virtual TI scout: seven synthetic LGE images are derived automatically using 7 k-means clusters.

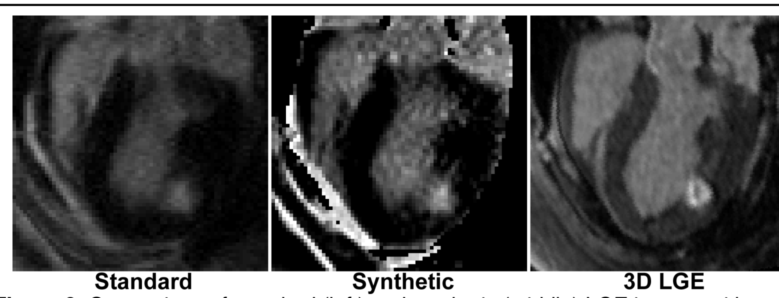

Figure 2. Comparison of standard (left) and synthetic (middle) LGE images with an RF lesion, as well as the reference 3D LGE reformatted to match the 2D plane (right).

Results: Our pooled data contained 19 short- and long-axis planes with different RF lesions. Figure 2 shows representative standard and synthetic LGE images (best TI only) with an RF lesion, as well as the reference 3D LGE reformatted to match the 2D plane. As shown in Table 1, compared with standard LGE, synthetic LGE produced significantly lower image quality and noise scores ($p < 0.05$), but both scores were greater than 3.0 (acceptable). Compared with 3D LGE, standard and synthetic LGE yielded 96 and 90% accuracy in lesion detection in the left ventricle, respectively.

Conclusions: This study demonstrates an approach to automatically derive several synthetic LGE images from a post-contrast cardiac T1 map, where the user can visually determine the best "TI" value to null the normal myocardium. (i.e., virtual TI scout). A theoretical benefit of synthetic LGE MRI is that it is insensitive to signal variations due to excitation and receive RF inhomogeneities. A future clinical study is warranted to evaluate the clinical utility of synthetic LGE MRI derived from cardiac T1 mapping.

Table 1. Image quality, noise, and scar detection statistics.

Description	Standard LGE	Synthetic LGE
Image quality	4.2 ± 0.8	3.5 ± 0.8
Noise	4.0 ± 0.6	3.2 ± 0.6
Scar detection (%)	95.6 ± 12.8	90.3 ± 18.7

References: **[1]** Kim RJ et al., *Circulation* 1999;100:1992-2002. **[2]** Moon JC et al., *JCMR* 2013;15:92. **[3]** Hong K et al., *ISMRM* 2014:Program No. 7163 (abstract). **[4]** MacKay D, ISBN: 0521642981. **[5]** Fitts M et al., *MRM* 2013;70:1274-82.

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