COMBINED SEQUENCE FOR INTEGRATED 2D LGE IMAGING AND T_1 MAPPING IN A SINGLE-SCAN

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TARGET AUDIENCE: Scientists and clinicians interested in myocardial tissue characterization.

INTRODUCTION: Two dimensional late gadolinium enhancement (LGE) using an inversion recovery sequence is the clinical gold standard for imaging of scar in the left ventricle (LV)[1]. Myocardial T_1 mapping sequences potentially provide information about diffuse fibrosis[2]. LGE and T_1 mapping images are usually acquired using two different imaging sequences. SAPPHIRE has recently been proposed for arrhythmia in-sensitive LGE imaging and heart-rate independent myocardial T_1 mapping[3]. In this study, we sought to develop a 2D SAPPHIRE sequence for combined LGE/T_1 mapping enabling simultaneous evaluation of myocardial scar and fibrosis in a single breath-hold exam.

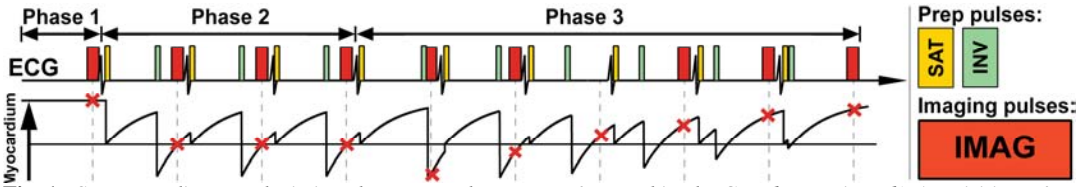

Fig. 1: *Sequence diagram depicting the proposed sequence for combined LGE/T1 mapping: 1) Acquisition of an image without magnetization preparation. 2) Multiple acquisitions of images with a combined saturation/inversion magnetization preparation, with the timing adjusted to null the healthy myocardium. 3) Multiple saturation/inversion prepared images, where the inversion time is linearly spaced over the applicable range.*

METHODS: ***Sequence:*** Myocardial T_1 mapping sequences consist of a series of single-shot T_1 weighted images acquired after application of a magnetization preparation such as an inversion, or a combination of saturation and inversion pulses. Therefore, these T_1 mapping sequences intrinsically contain a single-shot LGE sequence if the preparation pulse of one of the images of the T_1 weighted series is selected such that it nulls the healthy myocardium. To further improve SNR of the single shot LGE image, one can select more than one of the T_1 weighted images with the same inversion time to null the healthy myocardium. Figure 1 shows the schematic of the proposed sequence. 10 single-shot 2D images are acquired during a single breath-hold per slice in three phases. 1) The first image is acquired without magnetization preparation, to obtain a sample point of the fully recovered longitudinal magnetization. 2) Multiple images (referred to as LGE images) are acquired following the magnetization preparation with a saturation pulse at the detected R-wave, and an inversion pulse after a delay chosen to null the healthy myocardial tissue. 3) The remaining images are also acquired with the combined saturation/inversion magnetization preparation, but with a different inversion time in each of the images (linearly spread over the applicable R-R interval).

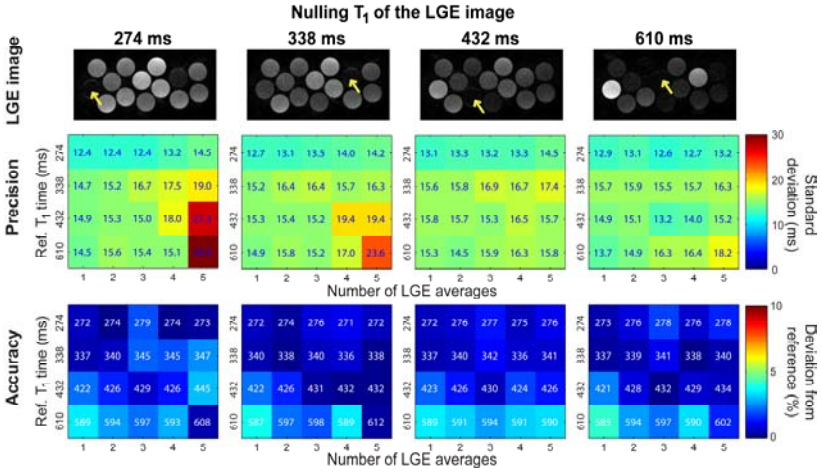

Fig. 2: *Phantom measurements, with the proposed sequence. The number of LGE image averages was varied between 1 and 5. Furthermore, the T_1 time that is nulled in the LGE image is varied between 270 and 610 ms (the vial to be nulled is indicated by the yellow arrow). The accuracy and the precision of the obtained T_1 maps is studied for T_1 values between 270 and 610 ms. Decreasing precision can be seen for high numbers of LGE image averages, if the studied T_1 time shows major deviation from the nulling T_1 in the LGE image.*

Subsequently, the final LGE image is obtained by averaging the multiple averages of the LGE image. A T_1 map is obtained by voxel-wise curve-fitting of the Bloch-equation based recovery model to the image intensities of all 10 images.

Imaging: All imaging was performed on a 1.5T Philips Achieva system. Phantom measurements were performed to study the impact of an increased number of averages for the LGE image on the T_1 quantification as a trade-off for improving the SNR of the final LGE image. Multiple measurements were performed where different phantom compartments with T_1 times between 270 and 610 ms (typical post-contrast range for healthy myocardium[4]) are nulled in the LGE image. The sequences were performed with 1 to 5 averages of the LGE image. The results were compared to a spin-echo reference. The precision of the proposed sequence was assessed as the standard deviation of the T_1 time within a homogenous phantom compartment. The accuracy was defined as the absolute deviation of the mean T_1 time from the spin-echo reference. Example in-vivo post-contrast LGE/T1 images were acquired in short-axis view (resolution = 1.9 x 2.5 mm, TR/TE/α=2.6/1.0/70°, 3 averages for the LGE image). Conventional SAPPHIRE T_1 maps (one image without magnetization preparation and 9 images with the inversion pulses linearly spaced over the R-R interval) were also acquired as reference with the same imaging parameters.

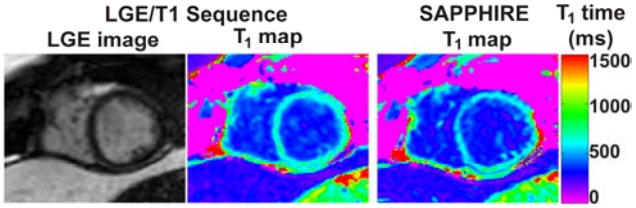

Fig. 3: *LGE images and post-contrast T_1 maps acquired 28 minutes after injection of 0.1 mmol/kg Gd- BOPTA. Proper nulling of the myocardium can be seen in the LGE images. The T_1 map quality with the proposed sequence is visually comparable to conventional SAPPHIRE. The T_1 times in the myocardium were assessed as 610 ± 77 ms with the proposed sequence and 581 ± 96 ms with conventional SAPPHIRE.*

RESULTS: Figure 2 shows the phantom results of the T_1 quantification. Proper nulling of the respective phantom component can be seen with the proposed sequence in the top row. A decreasing trend of the T_1 quantification precision can be seen for high numbers of LGE image averages in case of a major difference between the nulling T_1 in the LGE image and the studied T_1 time. Accordingly 3 LGE image averages were chosen for the in-vivo acquisition, as a trade-off between precision in T_1 maps and SNR in the LGE image.

Figure 3 shows a representative LGE image and T_1 map obtained with the proposed sequence compared to conventional SAPPHIRE. Proper nulling of the myocardium can be observed in the LGE images. T_1 maps acquired with the proposed sequence show visually comparable homogeneity and similar T_1 values (610 ± 77 ms with the proposed LGE/T_1 sequence vs. 581 ± 96 ms with conventional SAPPHIRE).

CONCLUSIONS: We have proposed a novel 2D sequence for combined LGE imaging and T_1 mapping that enables simultaneous evaluation of focal and diffuse fibrosis in a single scan.

REFERENCES: 1. Kim, R.J. NEJM, 2000; 2. Messrohgli, D.R. Radiology, 2006; 3. Weingärtner, S. MRM, 2013; 4. Ilse, L. JACC, 2008