Black Blood Late Gadolinium Enhancement (BB-LGE) using a joint T_2 Magnetization Preparation and Inversion Preparation

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Target Audience Scientists and clinicians who are interested in Late Gadolinium Enhancement (LGE), and/or Black-Blood (BB) imaging.

Introduction LGE allows depiction of scar/fibrosis in patients with cardiovascular disease. In this sequence, imaging is acquired after application of an inversion pulse to create a contrast difference between healthy myocardium and scar based on T_1. However, blood and scar have similar T_1, which often makes depiction of sub-endocardial scar challenging. In addition, in thin structures such as right ventricle or left atrial scar, similar signal level of blood and myocardium make visualization of scar very challenging. Several methods have been proposed to increase the blood-scar contrast including a double inversion technique [2], and T_2-prepared (T_2prep) sequences [3,4]. However, all these approaches suffer from either reduced SNR or reduced scar-myocardium contrast. Moreover, most of these techniques are not compatible with 3D acquisition which has been recently emerging for complete heart coverage in viability imaging. In this work, we propose a novel pulse sequence that uses an optimized combination of an inversion pulse and a T_2prep composite pulse to simultaneously null both the healthy myocardium and blood signals, based on the natively higher T_2 value of the blood, producing a black-blood LGE (BB-LGE) image without significant loss in the scar-myocardium contrast. We also developed a quick navigation sequence, analogous to the Look-Locker [5], to help determine the ideal nulling time before imaging.

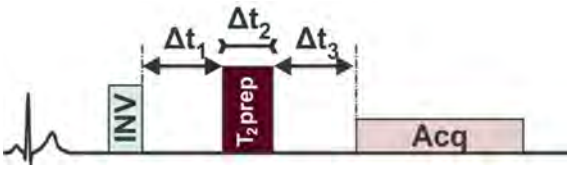

Figure 1. Pulse sequence schematic. A T_2prep pulse is inserted between the inversion pulse and the data acquisition. By changing the T_2prep duration (Δt_2), the time between the inversion and the T_2prep (Δt_1) and the time between the T_2prep and acquisition, one can control the contrast between different tissues, specifically healthy myocardium, blood and the infarct.

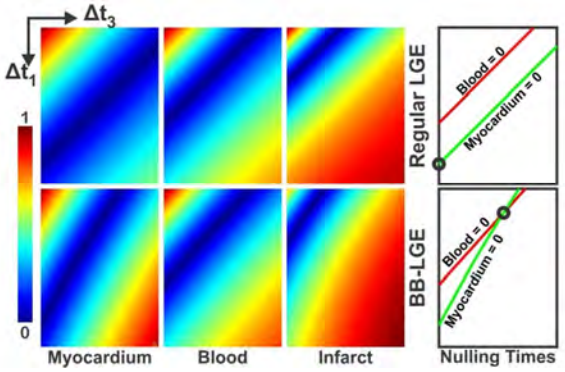

Figure 2. Simulated contrast maps showing the contrast of the three tissues when using conventional LGE, and the proposed BB-LGE. In conventional LGE sequence, the null lines of myocardium and blood do not intersect at a common point, preventing simultaneously nulling of both tissues. However, in the BB-LGE, a common null point can be obtained. We can also notice a slight decrease (around 10-15%) in the infarct signal intensity when using the myocardium null point in regular LGE and the myocardium-blood common null point in BB-LGE (black circles in the nulling times maps).

Methods Pulse Sequence: Fig. 1 shows the schematic of the proposed sequence, where a T_2prep is inserted between the inversion pulse and the acquisition.

Numerical Simulations: Simulations were performed using Bloch equation to study the effect of the proposed joint magnetization preparation of T_2prep and inversion pulses on the signal intensity of healthy myocardium, blood, and infarcted myocardium.

In-vivo Experiments: Six healthy adult subjects and 3 patients with suspected scar (35±21 y, 4 males) were imaged using a 1.5T Philips scanner. A standard LGE sequence was used to acquire a stack of five 2D short-axis slices, and one long-axis slice 20 min after Gd-contrast injection with the following parameters: FOV = 320×320mm^2, slice gap = 5mm, in-plane resolution = 1.5×1.5 mm^2, slice thickness = 10mm, TR/TE = 6.2/3.0ms, α = 25°, SENSE rate = 2, acquisition window = 80 ms, NSA = 2, breath-hold = 8s per slice. Then, the proposed BB-LGE, with the same sequence parameters, was used to acquire the same slices while setting the sequence timing to the null point of both the normal myocardium and the blood pool. The BB-LGE was preceded by a short navigation scan to determine the timing parameters that achieve the perfect nulling of both blood and myocardium signals. In one patient, we used a 3D acquisition with FOV = 320×320×40mm^2, and isotropic spatial resolution of 1.5mm^3.

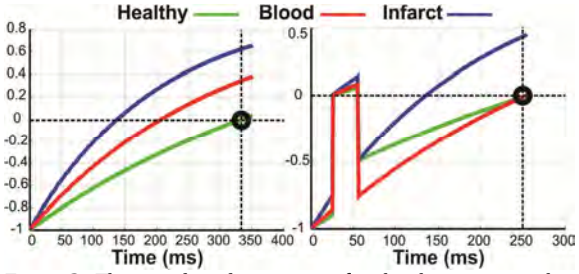

Figure 3. The signal evolution curve for the three tissues when using conventional LGE and the proposed BB-LGE sequences. While the blood signal is around 75% of the scar signal at the myocardium null point (i.e. low contrast between blood and scar) in regular LGE, both myocardium and blood were simultaneously nulled in BB-LGE.

Results Numerical Simulations: Fig. 2 shows the normalized signal intensity in healthy myocardium, blood and infarct tissues for different values of Δt_1 and Δt_3, and for a specific example of Δt_2=0, resulting in the conventional LGE, and Δt_2 =35ms resulting in the proposed BB-LGE. Upon choosing the nulling point in each sequence, Fig. 3 shows the signal evolution curve through time for the three tissues.

In-vivo Experiments: Fig. 4 shows examples of the BB-LGE images in two healthy subjects (i.e. no infarct), and three patients with an infarction (2D acquisition for the first two patients, and isotropic 3D acquisition for the third one).

Conclusion A new BB-LGE sequence was developed to simultaneously null both healthy myocardium and blood pool in both 2D and 3D LGE sequences based on the higher T_2 value of the blood.

References

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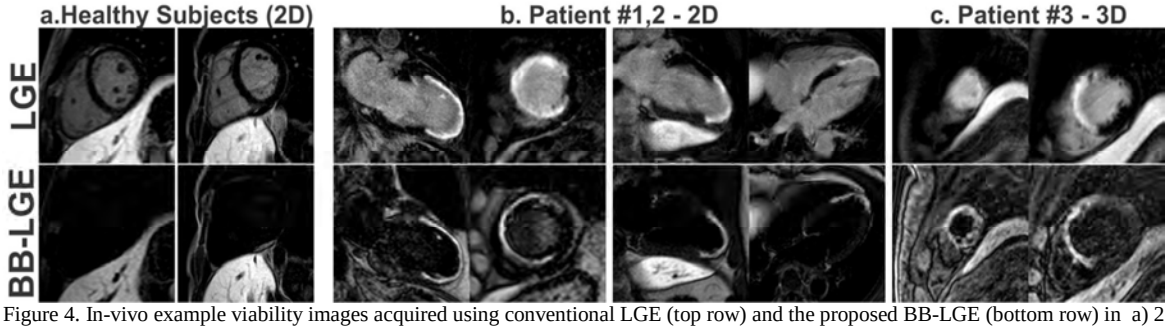

Figure 4. In-vivo example viability images acquired using conventional LGE (top row) and the proposed BB-LGE (bottom row) in a) 2 healthy subjects, b) 2 infarct patients imaged with 2D acquisition, and c) a patient with 3D acquisition. In all examples, the proposed sequence successfully nulled both the healthy myocardium and the blood pool, while retaining the infarct enhancement, which facilitates the delineation of the subendocardial scar.