# ESMRMB 2020- 37th Annual Scientific Meeting

## A multipurpose numerical simulation tool for late gadolinium enhancement cardiac MR imaging

Sina Amirrajab[1], Cristian Lorenz[2], Juergen Weese[2], Marcel Breeuwer[1,4]

[1]Biomedical Engineering Department, Eindhoven University of Technology, Eindhoven, The Netherlands, [2]Philips Research Laboratories, Hamburg, Germany, [3]Philips Healthcare, MR R&D – Clinical Science, Best, The Netherlands

## Introduction

Bloch equation-based numerical simulation tools for cardiac magnetic resonance (CMR) have provided great potential for various applications in medical imaging including myocardial first-pass perfusion quantification, fetal CMR imaging, and image database generation[1–3]. The MRXCAT[4] approach grounded on the XCAT[5] anatomical phantom has shown remarkable utility for simulating cine and perfusion images. However, the application of late gadolinium enhancement MRI (LGE) for myocardial infarction imaging has not been investigated. In this work, we extend the MRXCAT tool for cardiac LGE image simulation by implementing two clinical sequences, defining relevant imaging parameters, contrast agent dynamics, and incorporating two patterns of myocardial infarctions (MI).

## Methods

To create virtual patients with MI, we utilize our modified version of the XCAT phantom with heart trabeculation[6]. We create two patients with transmural and subendocardial MI patterns associated with coronary artery disease and the extend of the infarct and its location correspond to the area of the heart which is supplied by specific coronary arteries[7]. To simulate LGE images, we extend the MRXCAT with inversion recovery steady state free precession (IR-SSFP) and inversion recovery gradient echo (IR-GRE) MR sequences for bright blood imaging[8]. The relaxation rate for the infarct area linearly depends on the contrast agent concentration and its relativity according to the formula shown in the pipeline depicted in Figure 1.

## Results and Discussion

As shown in Figure 2, simulated images with variable inversion times demonstrate that MI visibility is sensitive to the inversion time and the scar-to-myocardium contrast is maximized when the signal of normal myocardium is nulled. The inversion time could be optimized to obtain adequate contrast between the blood pool and subendocardial MIs. Blood pool to normal myocardium contrast is higher in the IR-SSFP sequence compare to the IR-SPGR which is considered as one of the advantages of using

a steady state sequence in clinical routine. The sensitivity of the MI signal to the inversion time is lower in gradient echo sequence, which suggests robustness in detecting of MIs.

## Conclusion

In this paper, we extend the application of MRXCAT for LGE cardiac MRI simulation. This extension provides an opportunity to compare, estimate, and optimize sequences to achieve high contrast between the infarct region, normal myocardium, and blood pool. Moreover, a population of images with variable scar geometry, location, and size can be generated to aid the development of deep learning-based cardiac disease classification algorithms. Implementing the phase-sensitive reconstruction technique[9], the dark blood LGE sequence[10], and evaluating the simulated images in real clinical tasks are considered as future research.

## References


1. Wissmann, L. *et al*. *J. Cardiovasc. Magn. Reson.* 19, 11 (2017).
2. Roy, C. W. *et al*. *J. Cardiovasc. Magn. Reson.* 21, 1–12 (2019).
3. Tobon-Gomez, C. *et al. Magn. Reson. Med.* 65, 280–288 (2011).
4. Wissmann, L. *et al*. *J. Cardiovasc. Magn. Reson.* 16, 63 (2014).
5. Segars, W. P. *et al*. *Med. Phys.* 37, 4902–4915 (2010).
6. Amirrajab, S. *et al*. *Proc. 28th ISMRM* (2020).
7. Vöhringer, M. *et al*. *Herz* 32, 129–137 (2007).
8. Kellman, P. *et al*. *J. Magn. Reson. Imaging* 36, 529–542 (2012).
9. Kellman, P. *et al. Magn. Reson. Med.* 47, 372–83 (2002).
10. Kellman, P. *et al*. *J. Cardiovasc. Magn. Reson.* 18, 1–11 (2016).

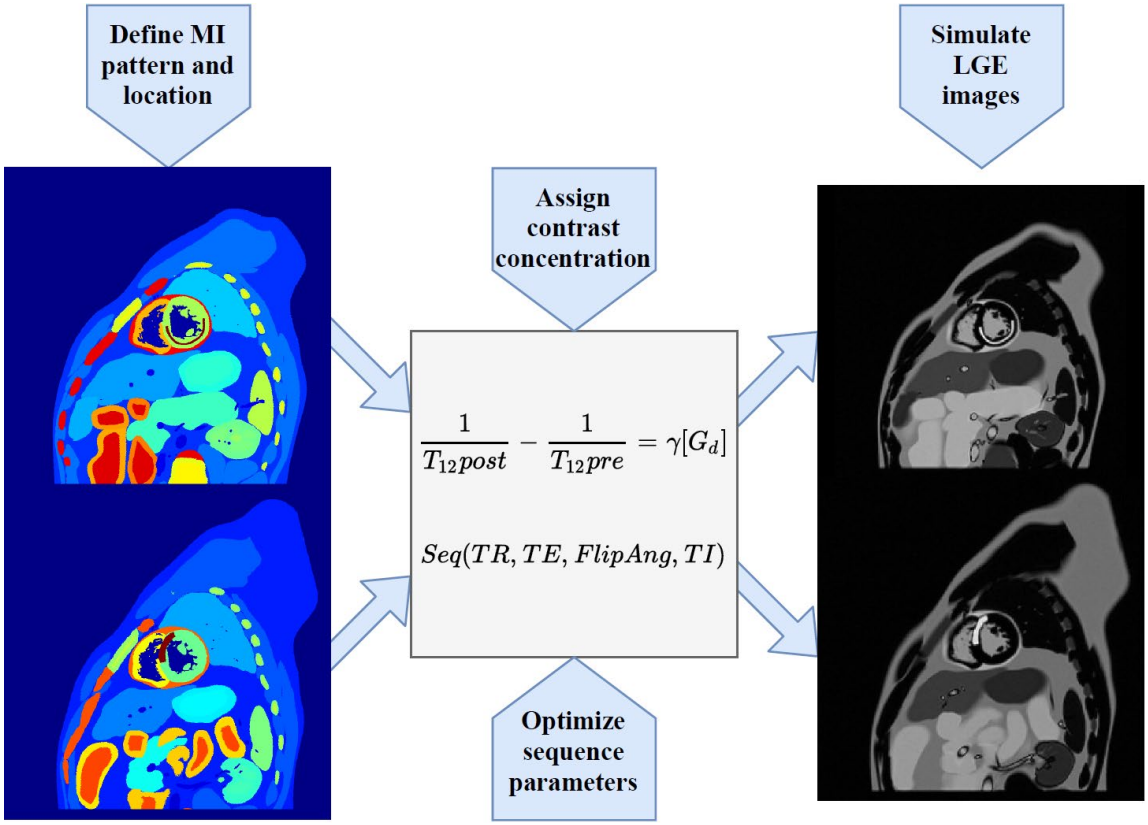


*Figure 1 LGE image simulation overview for two myocardial infraction patterns incorporated into the left ventricular myocardium (left). Parameterized tissue and sequence parameters to optimize the contrast (middle) and late gadolinium enhancement simulated images (right).*

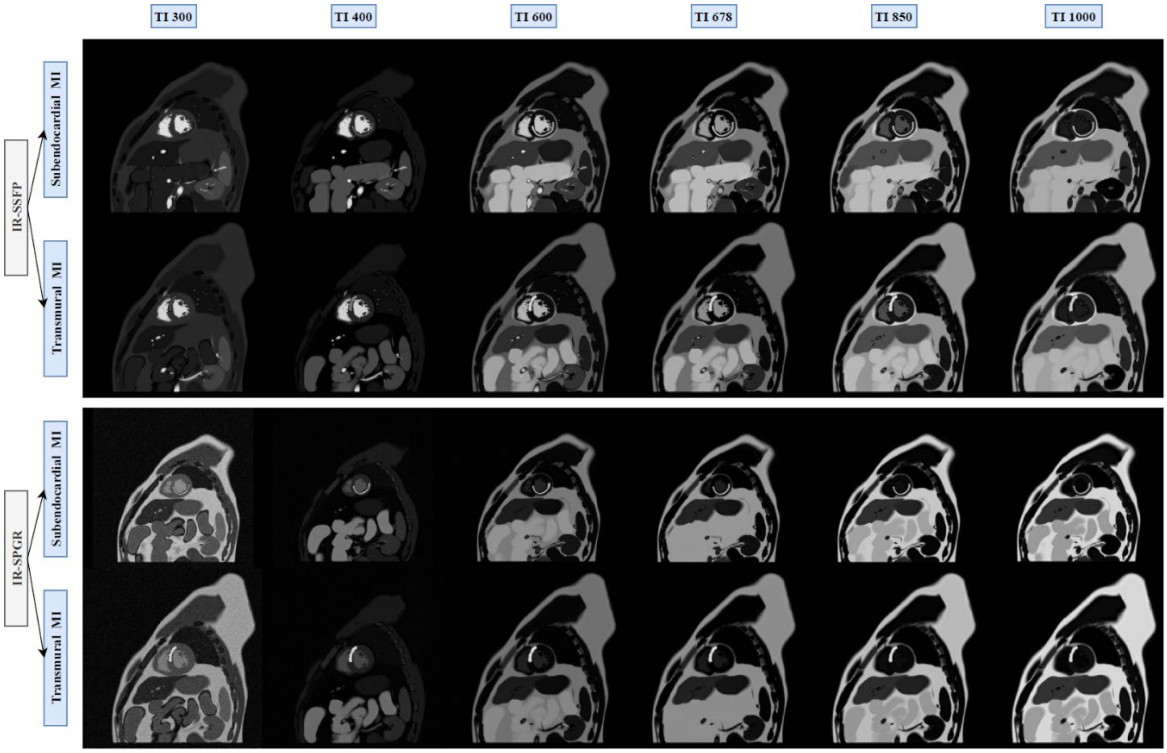


*Figure 2 inversion recovery steady state (IR-SSFP) and gradient echo (IR-SPGR) sequences with variable inversion time for subendocardial (1st and 2nd rows) and transmural (3rd and 4th rows) myocardial infarctions. Given the chosen T1 relaxation time for the myocardium, the inversion time to null the myocardium signal is around 678ms.*