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Generation of Realistic and Heterogeneous Virtual Population of Cardiovascular Magnetic Resonance Simulated Images

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INTRODUCTION

This study investigates an approach to generate a realistic, heterogeneous database of simulated cardiac MR images to aid the development of fully automated and generalizable deep-learning based segmentation algorithms, less sensitive to variability in CMR image appearance.

METHODS

- **Anatomical model** is based on male and female XCAT anatomical phantoms[1] with controllable parameters.
- **MR image simulation** is based on the improved version of MRXCAT physics-based CMR image simulation approach[2].
- **Validation of simulated images** is based on similarity metrics comparing the signal intensity distribution with real.

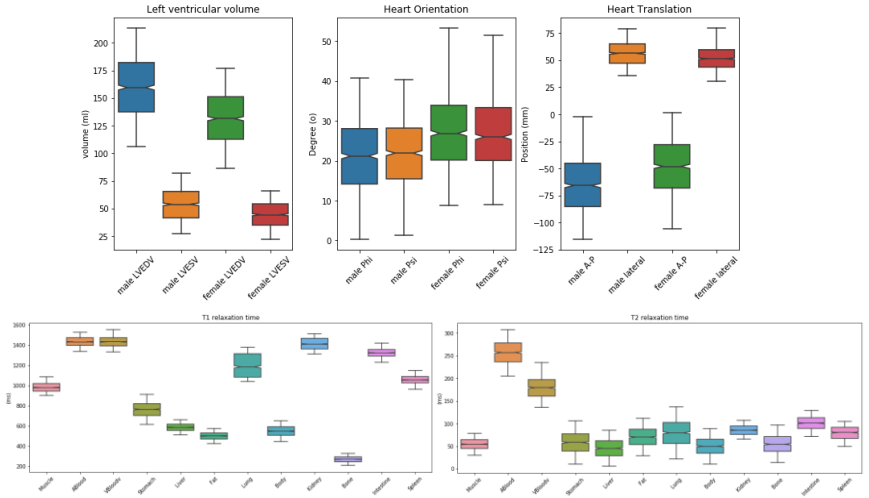
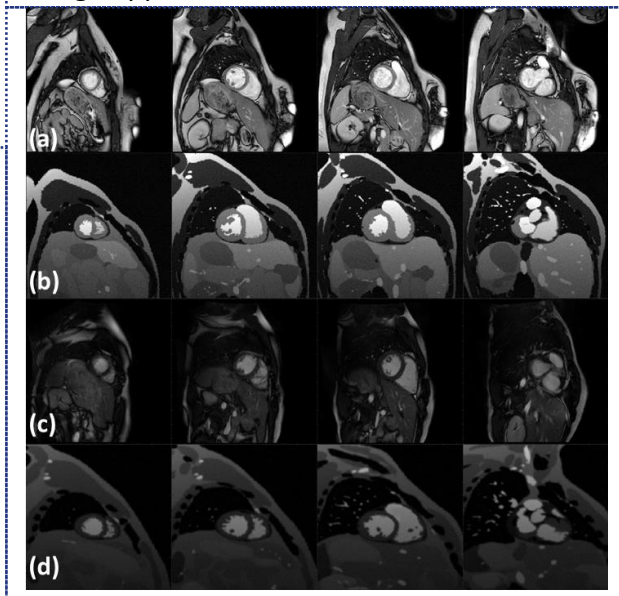


Figure 1(a) Anatomical parameters[3] include Left ventricular volumes of the heart at end-diastolic and end-systolic phase together with heart orientation and rotation within the torso for male and female anatomies. (b), (c) ranges of MR relaxation T1 and T2 parameters[4] for 12 organs, respectively.

RESULTS

Figure 2 Visual qualitative image appearance comparison. Real images acquired by different MR vendors (a,c) and simulated counterparts (b,d) at different slices of the short axis view of the heart. For the given same sequence parameters, image appearance and contrast for simulated is matched to real.



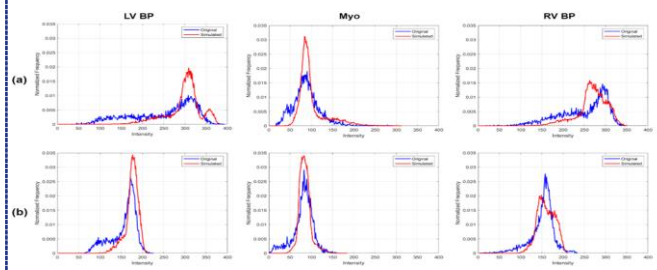


Figure 3 Representative signal distributions of the LV blood pool, LV myocardium and RV blood pool at end diastolic phase for real images and their counterparts shown in figure 2. Rows (a) and (b) correspond to real and simulated image pairs in figure 2 (a, b) and (c, d), respectively.

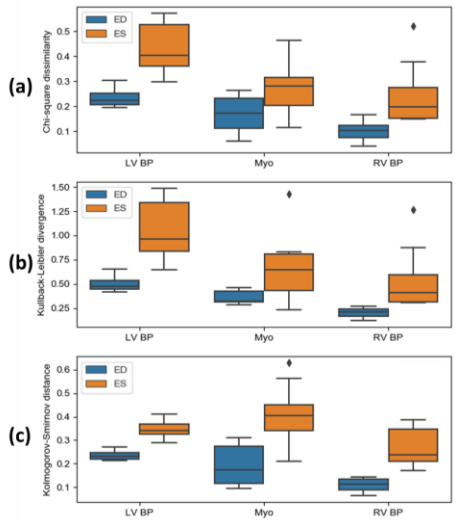


Figure 4 Plot of the (a) Chi-square dissimilarity metric ($\chi 2$), (b) Kullback-Leibler divergence (KL) and (c) Kolmogorov-Smirnov distance (KS) at (ED) and (ES) phases portraying quantitative differences between signal intensity distributions of real and simulated MRI data per tissue. Note that smaller values indicate a better similarity match in all cases (value of 0 being a full match).

CONCLUSION

- Simulated images are **quantitatively and qualitatively comparable** to real CMR images, and thus have a potential use in improving segmentation method.
- This population also provides **accurate ground truth** without the need for expert delineation and it can significantly boost the **generalization capability** of automated segmentation to unseen data.
- Initial experiments confirm that adding simulated data into the training set with real images has a **positive effect on the performance of the network** trained for segmentation[5].
- Such data can pave the way towards highly accurate and more efficient **large-scale multi-site and multi-scanner studies**.

[1] Segars WP et al. *Med Phys*2010. [2] Wissmann L et al. JCMR 2014. [3] Kawel-Boehm N et al. *JCMR* 2015. [4] Stanisz GJ et al. *MRM*. 2005. [5] Al Khalil Y et al. Proc. ISMRM 2020.