Towards Generating Realistic and Heterogeneous Cardiac Magnetic Resonance Simulated Image Database for DL-based Segmentation

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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 (DL) based segmentation algorithms, less sensitive to variability in CMR image appearance.

• Why do we need heterogeneous database for DL-based segmentation algorithm? Because accuracy and performance is dramatically degraded by inherent large variabilities in CMR image data: i) heterogeneous image contrast across sites and vendors ii) inter-expert error in delineating the ground truth iii) diverse range of image artifacts and noise levels.

• Generating a virtual population of simulated CMR images, including a wide range of variability, serves as a promising solution for improving the generalizability potential of DL methods.

• This could provide the “true ground truth”, since the anatomical model used for simulation provides directly the true tissue labels. There is no need for expert delineation for simulated images.

METHODS
• Anatomical model is based on the Visible Human Project male and female XCAT anatomical phantoms.
  - To create the population, we alter anatomical parameters depicted in Figure 1a.
  - For each organ, we assign a unique value of proton density, T1 and T2 relaxation time.

• MR image simulation is based on the MRXCAT physics-based CMR image simulation approach.
  - B-SSFP formula is used to generate image contrast with given sequence parameters (TR, TE and FA)
  - The parameters are modified such that the simulated signal intensity matches the signal intensity coming from real images.
  - The real images are acquired from two different vendors with similar scan protocols, but slightly different parameters, originating from two different imaging centers.

• Validation of simulated images is based on similarity and distance metrics.
  - We use Chi-square dissimilarity metric (χ2), Kullback-Leibler divergence (KL) and Kolmogorov-Smirnov distance (KS) to compare signal intensity distributions for the LV myocardium, LV blood pool and RV blood pool with their counterparts in real images.

RESULTS
• Visual comparison of real images acquired for two different sites and MR vendors and simulated counterparts.
• Image appearance and contrast are matched by tuning the simulation parameters.
• Corresponding signal intensity distributions for each of the three tissues.
• Distribution of the resulting χ2, KL and KS values for each of the tissues at ED and ES.

DISCUSSIONS & CONCLUSION
• Simulated images in this study are quantitatively and qualitatively comparable to real CMR images, and thus have a potential use in improving segmentation algorithms.
• This population also provides accurate ground truth without the need for expert delineation and it can significantly boost the generalization capability of automated segmentation methods 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.
• Such data can pave the way towards highly accurate and more efficient large-scale multi-site and multi-scanner studies.