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Data Article

Simulated late gadolinium enhanced cardiac magnetic resonance imaging dataset from mechanical XCAT phantom including a myocardial infarct

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ABSTRACT

The late enhanced magnetic resonance image dataset in this article is simulated using a mechanistic cardiac phantom that includes an myocardial infarct. Settings of the image simulation pipeline are adjusted such that high- and low-resolution images, with and without slice alignment artifacts, are simulated. Our article on the influence of image artifacts on image-based models of the cardiac electrophysiology is based on this data (Kruithof et al., 2021). This dataset provides image-analysis researchers a reference to perform validation of their methods using the included high-resolution ground truth image, a resource that is often unavailable clinically.

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Specifications Table

Subject	Cardiology and Cardiovascular Medicine
Specific subject area	Postinfarction cardiac imaging
Type of data	Image
How data were acquired	The data was simulated utilizing the mechanistic 4D eXtended CArdiac Torso (XCAT) heart phantom (Segars et al., 2010), Rhinoceros modelling software 6 (Rhino, 2020) and the openGTN MRI simulation pipeline (openGTN, 2020).
Data format	Raw
Parameters for data collection	Simulated data is generated using a virtual cardiac phantom containing a myocardial infarct. Mechanistic breathing parameters are adjusted to create late enhanced MR images with and without slice alignment artifacts. Multiple data simulations are performed to provide both high- and low-resolution images as well.
Description of data collection	The mechanistic 4D XCAT non-infarcted heart model is utilized as anatomical phantom and extended with a myocardial infarct scar. Bloch-equation based MR image simulation is performed using the simulation pipeline of openGTN et al., 2020 .
Data source location	Institution: Eindhoven University of Technology City: Eindhoven Country: the Netherlands
Data accessibility	https://github.com/sinaamirrajab/LGE_CMRI_Simulation [6]
Related research article	E. Kruithof, S. Amirrajab, M.J.M. Cluitmans, K.D. Lau, M. Breeuwer, Influence of Image Artifacts on Image-Based Computer Simulations of the Cardiac Electrophysiology, Computers in Biology and Medicine (Kruithof et al., 2021).

Value of the Data

- The simulated data includes a high-resolution ground truth image, which is typically missing in clinical datasets. In addition, it includes images with lower resolution and slice misalignments to mimic artefacts common in clinical data. All images are simulated for the same virtual cardiac phantom. The data also includes an infarct geometry which is designed to provide a high risk of cardiac arrhythmia.
- Researchers in the field of cardiac MR image analysis may benefit from these data as the performance of their methods can be tested for several image qualities, and validated by the ground truth image.
- The data can be used to validate image interpolation techniques as both high- and low-resolution images are included. The data can also be used for image artifact studies as both images with and without artifacts are available. Furthermore, the data is useful for image-based cardiac arrhythmia research as it includes an infarct area which is designed to provide a high risk of arrhythmia.

1. Data Description

The dataset contains three simulated late gadolinium enhanced magnetic resonance (MR) images which are created for the same virtual cardiac phantom with a myocardial infarct around the right coronary artery. The infarct area contains a conducting channel with dimensions reported to sustain ventricular tachycardia [7]. All three images are simulated as multiple two-dimensional short axis late enhanced MR images (TR: 3 ms, TE: 1.5 ms, FA: 40°, TI: 678 ms). Image1 is a high-resolution ground truth image with 0.738 × 0.738 mm voxel resolution and slice thickness of 1 mm, which cannot be created in clinic. Image2 is an 0.738 × 0.738 mm voxel resolution image with slice thickness of 5 mm, which is more common in clinic. Image3 is an 0.88 × 0.88 mm voxel resolution image with slice thickness of 6 mm. For this third image, slice misalignments up to 3.5 mm are included as well. The raw data is available on Github [6] in the form of NIfTI files. The long axis view of the three images are shown in Fig. 1.

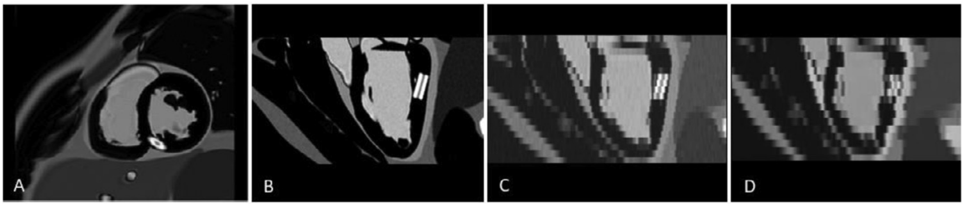

Fig. 1. (A) Short axis view and (B) long axis view of the high-resolution ground truth image1. Long axis view of the (C) low-resolution image2 and (D) low-resolution image3 including slice alignement artifacts. Figure from Kruithof et al. [1].

Image3 is a composition of 10 images created for different moments in the breathing cycle, to capture the movements of the organs resulting in slice misalignment. These 10 images and their corresponding masks are also available on Github [6] named LGE_IRSSFP_Respiratory_n__678_1.4_1.4_6_SNR_35_img and LGE_IRSSFP_Respiratory_n__678_1.4_1.4_6_SNR_35_msk, where 'n' can be replaced with the numbers 1 to 10. The msk files contain the ground truth mask data, displaying labels of the different tissues. Each of the 10 images and masks are created for the same mechanistic cardiac phantom, for slightly different moments in the breathing cycle.

2. Experimental Design, Materials and Methods

The simulated data is created by utilizing the mechanistic 4D XCAT non-infarcted heart model [2] as an anatomical phantom. This model is extended with a cylindrically shaped infarct divided in two areas with different scar densities, which is reflected in brightness differences in the MR images. The high scar density area, the core, and the lower density border zone areas are arranged such that a channel of border zone material crosses through the infarct core, as it is reported that this infarct composition gives rise to high risk of cardiac arrhythmia. The scar is located around the right coronary artery in the left ventricle wall, 2 cm below the short-axis valve plane (Fig. 2). The scar is designed in Rhinoceros modelling software 6 [3] and has an elliptical cross section and a length of 20 mm. The minor and major diameters are 10 and 20 mm for the outer border zone, 8 and 16 mm for the scar core and 3 and 6 mm for the border zone channel (Fig. 2). These dimensions were chosen to match the average characteristics for critical channels observed clinically as described in [7], which are defined as arrhythmia sustaining channels. For the placement of the designed scar inside the XCAT heart model, we first import the XCAT NURBS surfaces into Rhinoceros. Then the most inner surface of the myocardium and the coronary artery are selected as the guidance for locating the scar. We use operations such as

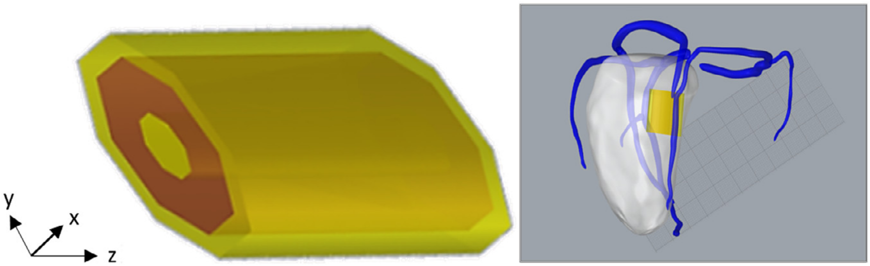

Fig. 2. Designed infarct geometry for the XCAT heart phantom. The scar core is visualized in red, the outer border zone and border zone channel in yellow. Figure from Kruithof et al. [1].

translation and rotation to attach the scar to the desired location, as shown in Fig. 2. The most outer surface of the heart model is finally used to ensure that the scar is completely enclosed within the myocardium. This extended XCAT heart model with scar is used as the anatomical phantom for the MR image simulation.

LGE MR images of the XCAT anatomical phantom complemented with the scar are simulated using the openGTN MRI simulation pipeline which is based on the Bloch-equations [4,5]. The ground truth images are simulated with the XCAT phantom without any breathing motion, i.e. no misalignment artifacts are present in these images. Another image containing slice misalignments up to 3.5 mm is simulated to mimic clinical slice alignment artifacts (6 mm slice thickness). Such slice misalignments in clinical images are caused by movements of the heart due to breathing. Multiple phantoms are created at different time points across one breathing cycle to capture the organ movements induced by the XCAT motion model. The total duration of the breathing cycle is set to 5 s and the movement of the heart during breathing is set to 0.5 cm in-plane and 1.0 cm out-of-plane [1]. This results in misalignment artifacts up to 3.5 mm, which is similar to those in clinical late enhanced MR images. The LGE image simulation is performed in 2D slice-by-slice. The slice misalignment is then mimicked by combining slices created at the same time point in the cardiac cycle, but at slightly different time points in the breathing cycle of the XCAT phantom.

Ethics Statement

Informed consent and approval by an Ethical Medical Committee is not needed as the simulated MRI data is created for a mechanistic virtual phantom, instead of for a real patient.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

CRediT Author Statement

Evianne Kruithof: Conceptualization, Writing – original draft; **Sina Amirrajab:** Methodology, Software; **Kevin D. Lau:** Supervision, Writing – review & editing; **Marcel Breeuwer:** Supervision, Writing – review & editing.

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