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Influence of image artifacts on image-based electrophysiological simulations using simulated XCAT phantom MR images

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Introduction

Myocardial infarct (MI) patients have an increased risk of scar-based ventricular tachycardia (VT) and therefore sudden cardiac death [3]. Late gadolinium enhancement (LGE) magnetic resonance (MR) imaging provides the geometric extent of MI scar, but lacks functional information to assess VT risks. Image-based electrophysiological (EP) models provide a personalized solution to understand the functional relationship between MI and VT emergence [3, 4].

The geometry of the enhanced scar can be reconstructed by thresholding and interpolation of the LGE image. However, scan parameters and image artifacts can affect the reconstructed result and therefore the EP simulation outcome. To our knowledge, the effect of slice thickness and slice alignment artifacts on detected scar geometry and EP simulation remains uncharacterized. We investigated these effects by simulating LGE images on the XCAT anatomical phantom with different slice thickness and slice alignment artifacts.

Methods

Deng [3] reports that conduction channels (CC), which are channels of remodeled living tissue through the dead scar core, sustain 63% of the induced VTs. Rhinoceros modeling software [5] is used to design a cylindrically shaped scar with inner layers for CC, which is added around the right coronary artery in the left ventricle (LV) wall of the XCAT heart model (Fig. 1).

Numerical Bloch-based MR image simulation is performed to generate inversion recovery LGE images as introduced by [1] with slice thickness of 5 and 1 mm. Slice alignment artifacts are simulated by combining slices of 10 images created at slightly different time points across two breath cycles in the parameterized XCAT model (Fig. 1).

The simulated images are segmented and interpolated to create a volumetric LV mesh with infarct regions. EP simulations are performed in CARPentry [2] using the Ten Tusscher ionic model, which is adapted to account for the remodeled CC tissue properties [3, 4]. Baseline pacing is performed in six locations, followed by a premature stimulus to induce VT (Fig. 1). For each model, a vulnerable window (VW) is identified that defines the time intervals at which VTs are induced (Fig. 2).

Results & Discussion

Table 1 shows small changes in scar volume measurements for images with variable slice thickness compared to the initial ground truth. However, these minor changes significantly affected EP simulation results, reflected by a shift in VW (Fig. 2). Low-res image partial volume effects enlarge the reconstructed CC width compared to the high-res image result. This reduces the delay in CC repolarization and the low-res model is therefore more vulnerable to premature stimuli entry at shorter time intervals.

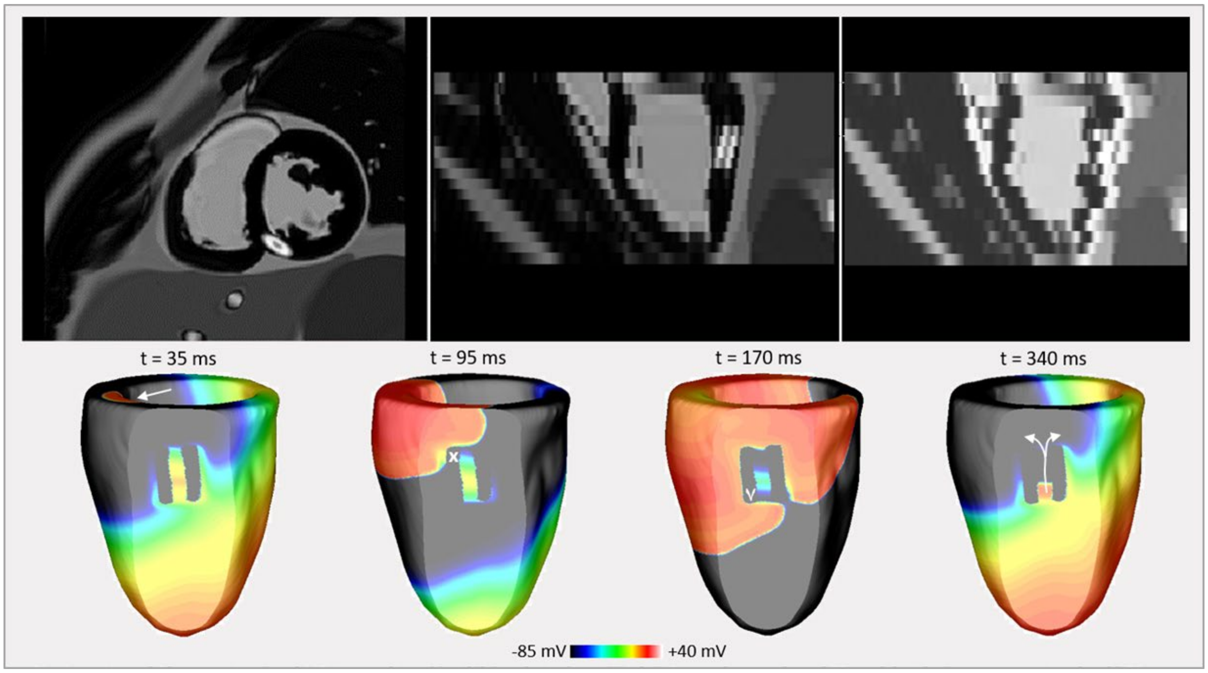

Fig. 1 Upper) Phantom simulated MR image aligned (middle) and misaligned (right). Bottom) Image-based EP model with a) premature stimulus, b) EP wave block at entrance of depolarized CC, c) EP wave enters repolarized CC and d) EP re-entering tissue via CC.

	XCAT	Low-res	High-res
LV [ml]	115.56	108.27	115.62
Total scar [ml]	2.24	2.40	2.42
Core [ml]	1.24	1.38	1.45
CC [ml]	1.00	1.02	0.97

Table 1 Volumes of XCAT ground truth and image based reconstructions

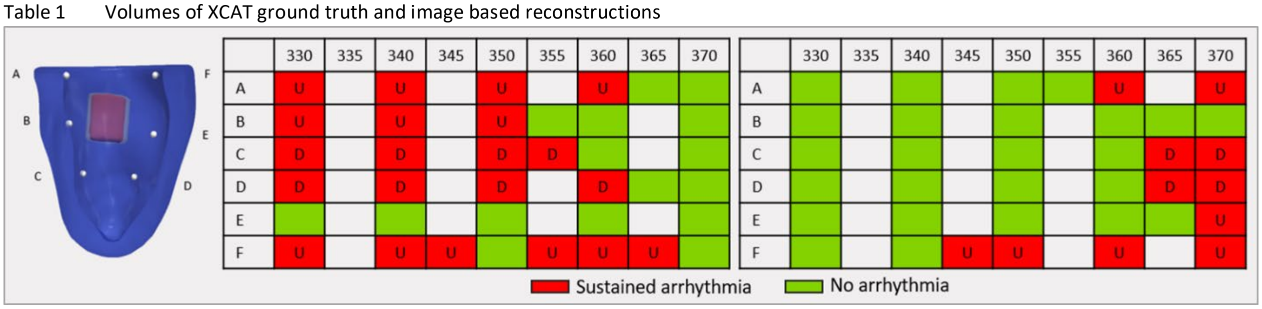

Fig. 2 Pacing locations (left) and their vulnerable windows for models based on low- (middle) and high-res (right) XCAT phantom MR images. ‘U’ and ‘D’ type VTs are sustained by EP waves propagating upwards or down through the CC.

References

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