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JOINT AAPM | COMP MEETING

Model-Based Registration of Ex Vivo Optical Mapping to Pre-Treatment 3D Imaging Using Photogrammetry In Porcine STAR

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PURPOSE / OBJECTIVES

Stereotactic arrhythmia radiotherapy (STAR) is an emerging treatment for ventricular tachycardia (VT) that uses radiation to modulate cardiac electrophysiology (EP) and reduce VT. Registering radiation planning 3D imaging to cardiac optical maps will enable observation of EP's correlation with radiation dose in a porcine model. This work extends previous work of an unrolled LV preparation to a whole-heart Langendorff model.

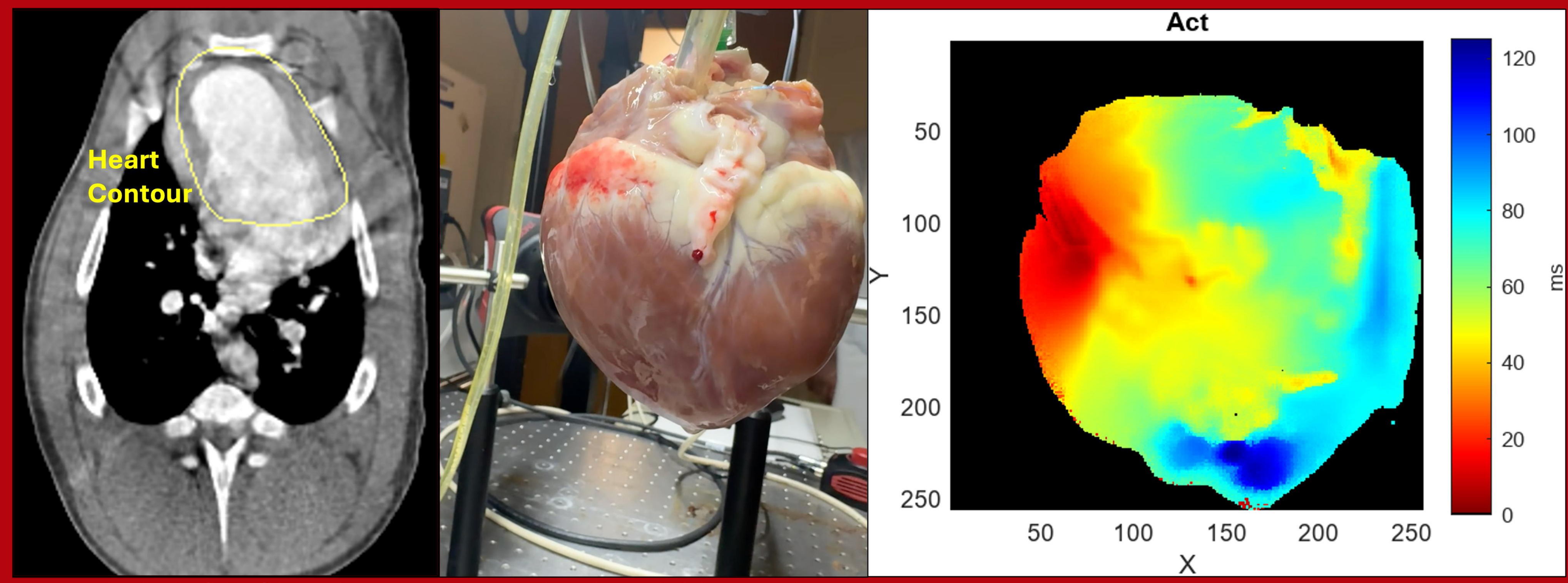
MATERIAL & METHODS

Ventricular meshes were generated from pre-treatment MRI contours. The American Heart Association 17-segment model was fit to the LV mesh. Following STAR, the heart was excised for optical mapping, and cardiac activity was recorded using fluorescent dye and a high-speed camera. Visible-light images of the heart in the mapping pose were used to reconstruct a 3D mesh via photogrammetry, serving as surrogate geometry for aligning optical mapping to pre-treatment imaging. The 17-segment model was applied to the surrogate mesh to enable registration to the MRI-derived meshes in a shared coordinate system. Optical mapping-to-surrogate correspondence is being developed using a visible-light image acquired immediately before mapping to enable back-projection of the mapping to the 3D surrogate mesh. Photogrammetry accuracy was evaluated on a contour-derived 3D-printed phantom by comparing reconstructed and reference meshes (Dice, MDA, HD, HD95).

RESULTS

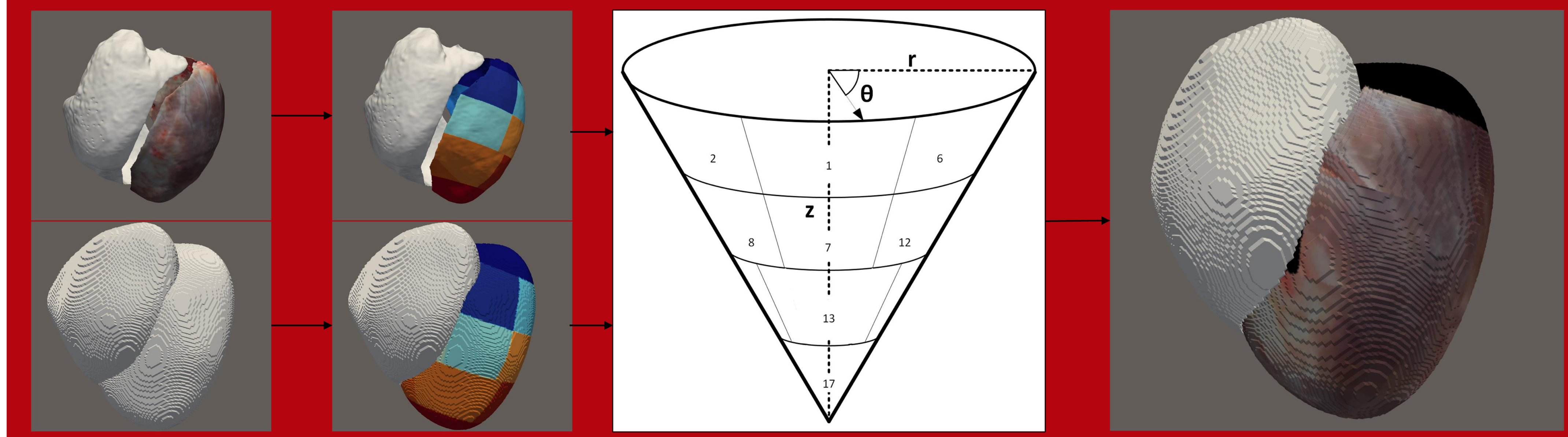
A 3D surrogate mesh of the excised heart in the optical mapping pose was generated via photogrammetry. The surrogate mesh was aligned to MRI-derived ventricular meshes using the 17-segment framework. Photogrammetry accuracy, measured with a 3D-printed, contour derived phantom and its corresponding contour reference, was Dice=0.98, MDA=0.53mm, and HD95=1.53mm. Optical map back-projection to the surrogate surface and registration-accuracy assessment will be performed in future work.

Radiation dose and cardiac electrophysiology exist in fundamentally different image modalities:

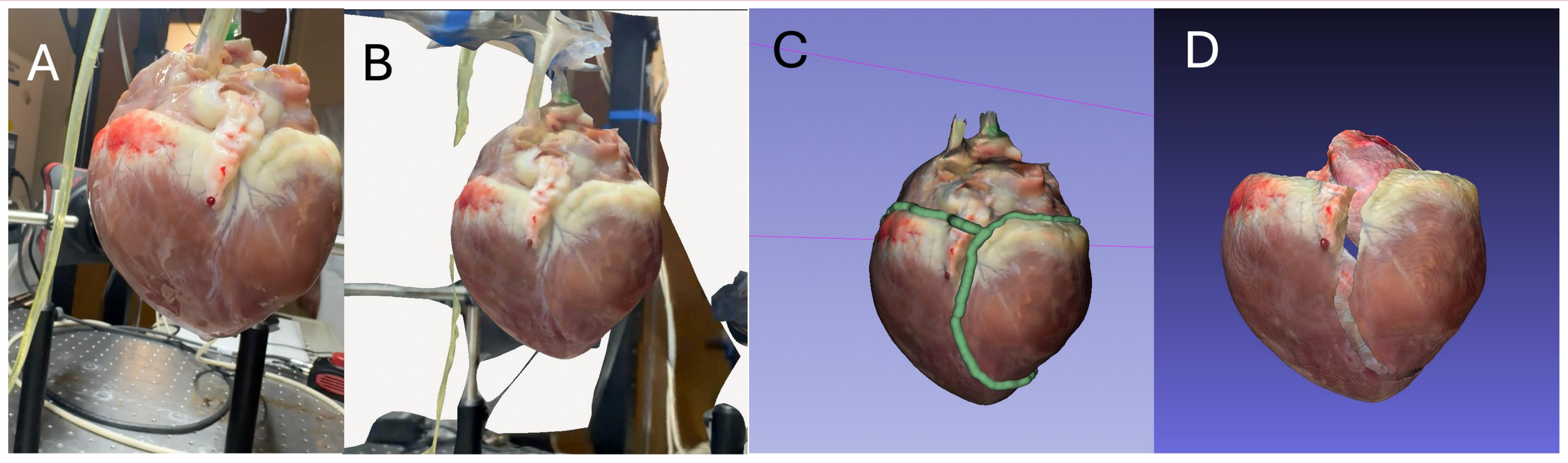


Axial CBCT of Pig Subject
Excised Heart in mapping position
Optical Map of Activation Times

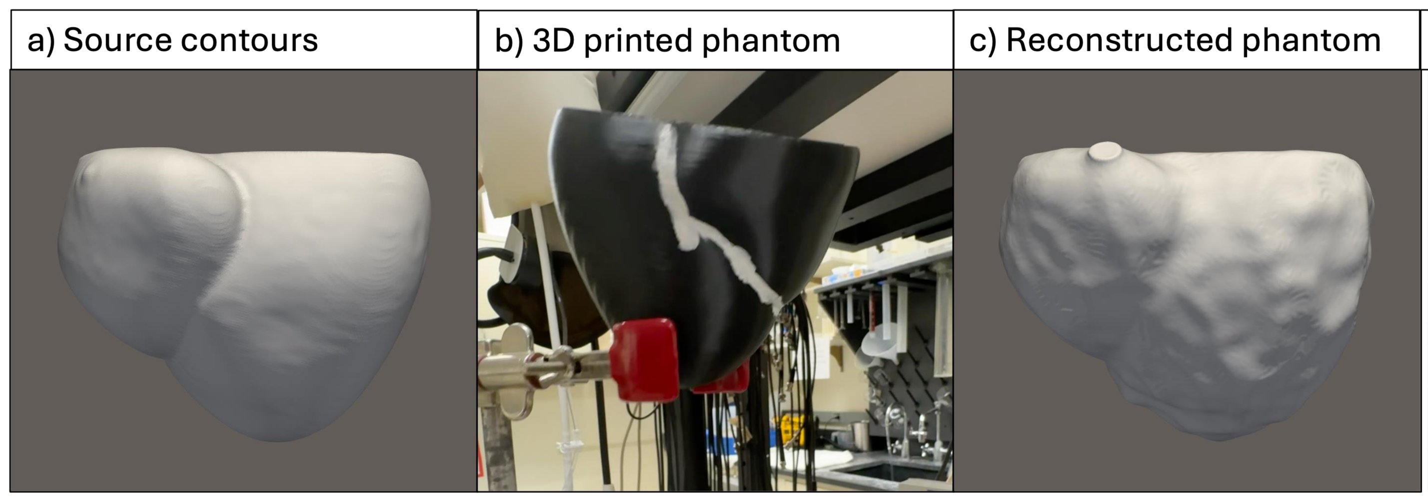
Model-based registration framework:



17-segment model applied to both data sets
17-segment model derived coordinate system is applied
Photogrammetry features applied to MRI LV mesh



a) Example image of the heart in the optical mapping position. b) 3D mesh of the excised heart generated via photogrammetry. c) Heart mesh with delineated interventricular and atrioventricular grooves. d) Separated left ventricle (LV) and right ventricle (RV) meshes. The LV and RV were separated into unique meshes to enable application of the 17-segment model to the LV surface on the 3D mesh.



d) Evaluation Results	
Dice	0.98
HD (Max)	4.29 mm
HD (95%)	1.53 mm
MDA	0.53 mm

a) MRI contours of porcine epicardium. b) 3D printed phantom generated from MRI contours. c) Reconstruction of the phantom geometry using photogrammetry. d) Results of quantitative evaluation of the photogrammetry and reference volumes. Results indicate high agreement between data sets.

SUMMARY / CONCLUSION

A model-based registration was developed to align pre-treatment MRI imaging to photogrammetry derived surface geometry in the optical mapping pose, enabling alignment of the radiation dose distribution to electrophysiology data acquired ex vivo. Ongoing work will project optical maps to this surface and quantify registration-accuracy.

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