2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

Clinical Application of Heart Digital Twin–Based InHeart-Guided Cardiac SBRT for Ventricular Tachycardia Using VMAT with High-Definition MLC

Weijun Xiong, PhD[1], Shu-chen Chang[1], Warren Fong[1], Jason Jacobson[1], Aviva Berkowitz[1,2] and Mark Hurwitz, MD[1,2*],
(1)Department of Radiation Medicine, Westchester Medical Center, Valhalla, NY
(2)New York Medical College, Valhalla, NY,
* Senior author

ABSTRACT

Purpose
Stereotactic body radiotherapy (SBRT) is an emerging noninvasive treatment for refractory ventricular tachycardia (VT). Precise target delineation and highly conformal dose delivery are critical due to cardiac motion and the close proximity of radiosensitive organs. This study evaluates the clinical application and dosimetric performance of cardiac SBRT planned using a heart digital twin generated by the InHeart application and delivered with VMAT utilizing high-definition (HD) multileaf collimators (MLC).

Methods
Two patients with refractory VT were included. In the first patient, a left ventricular assist device (LVAD) was present and incorporated into planning as a critical avoidance structure. In the second patient, SBRT targets were refined using noninvasive electrocardiographic mapping of VT induced through the patient's implantable cardioverter-defibrillator (ICD). The InHeart application analyzed cardiac CT/MRI to construct a three-dimensional heart digital twin, enabling identification of myocardial scar, arrhythmogenic substrates, and adjacent organs at risk (OARs) for target delineation. 4D CT Planning scan was taken and target structures were imported into the treatment planning from InHeart software. Treatment plans were generated using VMAT with a 6 MV flattening filter-free beams using HD MLC linear accelerator. A prescription dose of 25 Gy in a single fraction was planned. Dosimetric endpoints included target coverage, conformity, and OAR doses (lungs, esophagus, spinal cord, coronary arteries, and implanted devices). Patient-specific quality assurance was performed using standard measurement-based techniques.

Results
Both plans achieved ≥ 95% target coverage with the prescription dose and demonstrated high conformity (CI100%<=1.1) with steep dose gradients. The HD MLC enabled precise shaping of complex cardiac targets while maintaining OAR and implanted-device doses within institutional and published constraints. VMAT delivery provided efficient treatment times compatible with motion-managed workflows.

Conclusion
Heart digital twin–based InHeart-guided target delineation combined with VMAT SRS and HD MLC linac enables accurate, highly conformal, and clinically feasible cardiac SBRT for VT ablation, including complex scenarios involving LVADs and ICD-guided target refinement. This approach supports safe treatment delivery and demonstrates potential for broader clinical implementation.

INTRODUCTION

Stereotactic body radiotherapy (SBRT) has emerged as a promising noninvasive treatment option for patients with refractory ventricular tachycardia (VT) who are not candidates for, or have failed, conventional catheter ablation. Successful cardiac SBRT requires accurate identification of arrhythmogenic substrates and highly conformal dose delivery due to cardiac motion and the close proximity of critical cardiac and thoracic structures.

This study evaluates the clinical implementation and dosimetric performance of cardiac SBRT planned using a heart digital twin generated by the InHeart platform and delivered using volumetric modulated arc therapy (VMAT) with high-definition (HD) multi-leaf collimators (MLCs).

METHODS AND MATERIALS

Two patients with medically refractory VT underwent cardiac SBRT.

Patient 1: LVAD Case
The patient had a left ventricular assist device (LVAD), which was incorporated into treatment planning as a critical avoidance structure.
Special consideration was given to minimizing radiation exposure to the LVAD components while maintaining adequate target coverage.

Patient 2: ICD-Guided Mapping Case
VT targets were refined using noninvasive electrocardiographic mapping generated from VT induced through the patient's implantable cardioverter-defibrillator (ICD).
Electrophysiologic information was integrated with imaging data to improve localization of arrhythmogenic substrates.

Digital Twin Generation and Treatment Planning

The InHeart application analyzed multimodality cardiac CT and MRI datasets to generate a patient-specific three-dimensional heart digital twin. The model enabled:
Identification of myocardial scar regions
Localization of arrhythmogenic substrates
Visualization of adjacent organs-at-risk (OARs)
Delineation of target volumes for cardiac ablation
Target structures were imported into the Treatment Planning System.

Treatment plans were generated using:

Linear accelerator with HD-MLC
6 MV flattening filter-free (FFF) photon beams
VMAT delivery technique
Prescription dose: **25 Gy in a single fraction**

RESULTS

Dosimetric Performance

Metric	Patient 1	Patient2
PTV Volume (cm³)	56.3	161.4
PTV V25Gy (%)	105.5	99.3
CI100%	1.10	0.99
Lung V5Gy (%)	3.5	17.3
Maximum Esophagus Dose (Gy)	4.03	10.66
Maximum ICD/LVAD Dose (Gy)	0.44	0.35

Treatment Quality

Both plans achieved ≥95% target coverage with the prescription dose. Excellent conformity was observed with CI100% ≤ 1.1.Sharp dose falloff and steep dose gradients were achieved around complex cardiac targets. HD MLC technology enabled precise shaping of irregular target geometries. Doses to lungs, esophagus, implanted devices, and other critical structures remained within institutional and published constraints.

VMAT delivery provided efficient treatment times compatible with clinical motion-management workflows.
Discussion

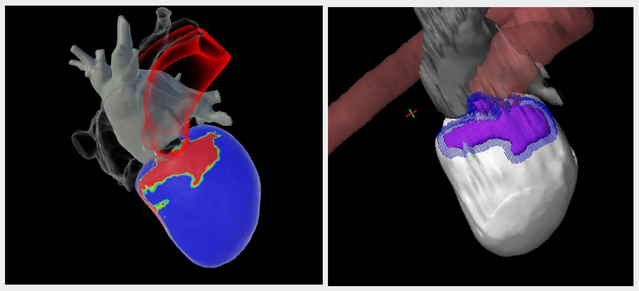


Figure 1. (a, left) InHeart heart digital twin demonstrating myocardial scar identification and arrhythmogenic substrate–based target delineation. (b, right) Planning target volume (PTV) imported and delineated in the Eclipse treatment planning system based on the InHeart digital twin.

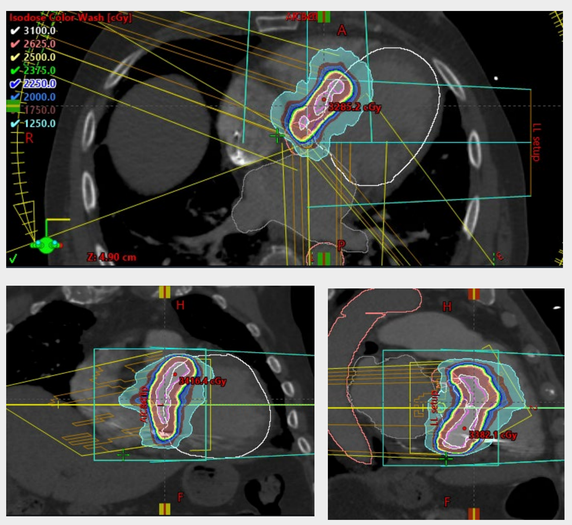


Figure 2. Isodose distribution of the cardiac SBRT plan displayed in the (a, upper) axial, (b, lower left) coronal, and (c, lower right) sagittal views. The treatment plan was generated in the Eclipse Treatment Planning System with a prescription dose of **25 Gy in a single fraction**. The planning target volume (PTV) was derived from the patient-specific heart digital twin generated using the InHeart platform. The plan achieved highly conformal target coverage while maintaining dose constraints to adjacent organs at risk

DISCUSSION

The InHeart digital twin platform facilitates integration of multimodality imaging and electrophysiologic information into the cardiac SBRT workflow. This approach improves visualization of arrhythmogenic substrates and supports personalized target delineation.

The use of VMAT with HD MLC enabled highly conformal dose distributions despite the complex anatomy of the heart and the presence of implanted devices. Successful treatment planning was achieved in challenging clinical scenarios involving both LVAD avoidance and ICD-guided target refinement.

These findings demonstrate the feasibility of incorporating advanced digital-twin technology into routine cardiac SBRT planning and delivery.

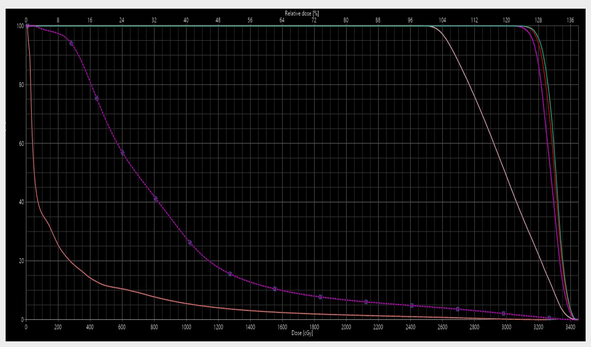


Figure 3. Dose–volume histogram (DVH) for Patient 1. The mean heart dose was **8.6 Gy**, with a maximum heart dose of **34.5 Gy**. Excluding the planning target volume (PTV), the maximum heart dose was **29.4 Gy**, and the mean heart dose was **7.73 Gy**. The great vessels received a mean dose of **2.23 Gy** and a maximum dose of **32.55 Gy**. The maximum esophageal dose was **4.03 Gy**, while the maximum lung dose was **8.98 Gy**. These results demonstrate effective target coverage while maintaining doses to surrounding critical structures within acceptable limits.

CONCLUSIONS

Heart digital twin–based InHeart-guided target delineation combined with VMAT and HD MLC enables accurate, highly conformal, and clinically feasible cardiac SBRT for ventricular tachycardia ablation.

This approach successfully supported treatment planning and delivery in complex clinical scenarios involving LVADs and ICD-guided target refinement while maintaining excellent target coverage and OAR sparing.

The integration of digital twin technology with advanced VMAT delivery represents a promising strategy for broader clinical implementation of noninvasive cardiac radioablation.

REFERENCES

1. Waks JW, Ellenbogen KA, Calkins H, et al. Stereotactic arrhythmia radioablation for refractory ventricular tachycardia: a systematic review and meta-analysis. *Heart Rhythm*. 2025;11838787. doi:10.1016/j.hrthm.2025.01.012
2. Patel R, Tan Y, Smith J, et al. Clinical outcomes of stereotactic body radiation therapy for ventricular tachycardia. *Red Journal*. 2025;0360-3016. doi:10.1016/j.ijrobp.2025.03.016

© Poster Template by Genigraphics® 1.800.790.4001 www.genigraphics.com