

Stereotactic arrhythmia radioablation for intramural basal septal ventricular tachycardia originating near the His bundle



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Introduction

Stereotactic arrhythmia radioablation (STAR) is a relatively novel noninvasive approach to treat ventricular tachycardia (VT) refractory to conventional antiarrhythmic and catheter ablation-based therapy. We report a case of recurrent basal intramural septal VT treated with STAR guided by fusion of 3-dimensional electroanatomic (EA) imaging, cardiac magnetic resonance imaging (MRI), and cardiac computed tomography (CT) without development of heart block or sustained VT followed out to 1 month after treatment.

Case report

A 73-year-old man with longstanding nonischemic cardiomyopathy, left ventricular (LV) ejection fraction of 45%, baseline right bundle and left anterior hemiblock, and multiple myeloma was referred for treatment of symptomatic, sustained VT. He had a history of hemodynamically tolerated VT that had been previously well suppressed on amiodarone, which had recently been discontinued owing to suspected intolerance.

He underwent electrophysiology study after experiencing recurrent, symptomatic, hemodynamically tolerated sustained monomorphic VT during the first night of his hospital admission (Figure 1A). Two separate LV summit origin VTs were induced with programmed stimulation and successfully treated with radiofrequency (RF) ablation at the LV endocardium directly adjacent to the aortic valve (Figures 1B–D). A third VT (Figure 1B) was then induced with triple ventricular extrastimuli from the right ventricular (RV) apex that more closely resembled the clinical tachycardia observed during

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KEY TEACHING POINTS

- Stereotactic arrhythmia radioablation (STAR) offers a potential noninvasive treatment option for intramural ventricular tachycardia (VT).
- Fusion of 3D electroanatomic maps and preprocedure cardiac magnetic resonance imaging and computed tomography may improve accuracy of STAR treatment to the suspected site of VT origin.
- In this single-case experience, no sustained VT or worsening atrioventricular conduction was noted out to 1 month following STAR therapy to the basal interventricular septum.

his initial presentation to the referring hospital. Based on 12-lead electrocardiogram, we suspected this VT to originate from the intramural high basal septum. This tachycardia was nonsustained and thus unable to be activation mapped. Extensive pace mapping was performed from the RV and LV endocardium, and from the intramural septal perforator coronary arteries. The best pace maps were observed from the RV basal septum just distal to the His bundle recording, though this location yielded only a 75% match of the clinical VT in 12 leads (Figure 1E).

Due to concern about causing heart block and potentially not effectively reaching the suspected basal intramural site of origin of the suspected clinical VT, RF ablation was not performed. Postprocedure transesophageal echocardiogram showed a left ventricular ejection fraction of 25%. The patient agreed to resume amiodarone owing to prior efficacy and was discharged home. He declined internal and external defibrillator devices.

Two months after hospital discharge, he was readmitted to a referring hospital with recurrent VT3. Due to concern about

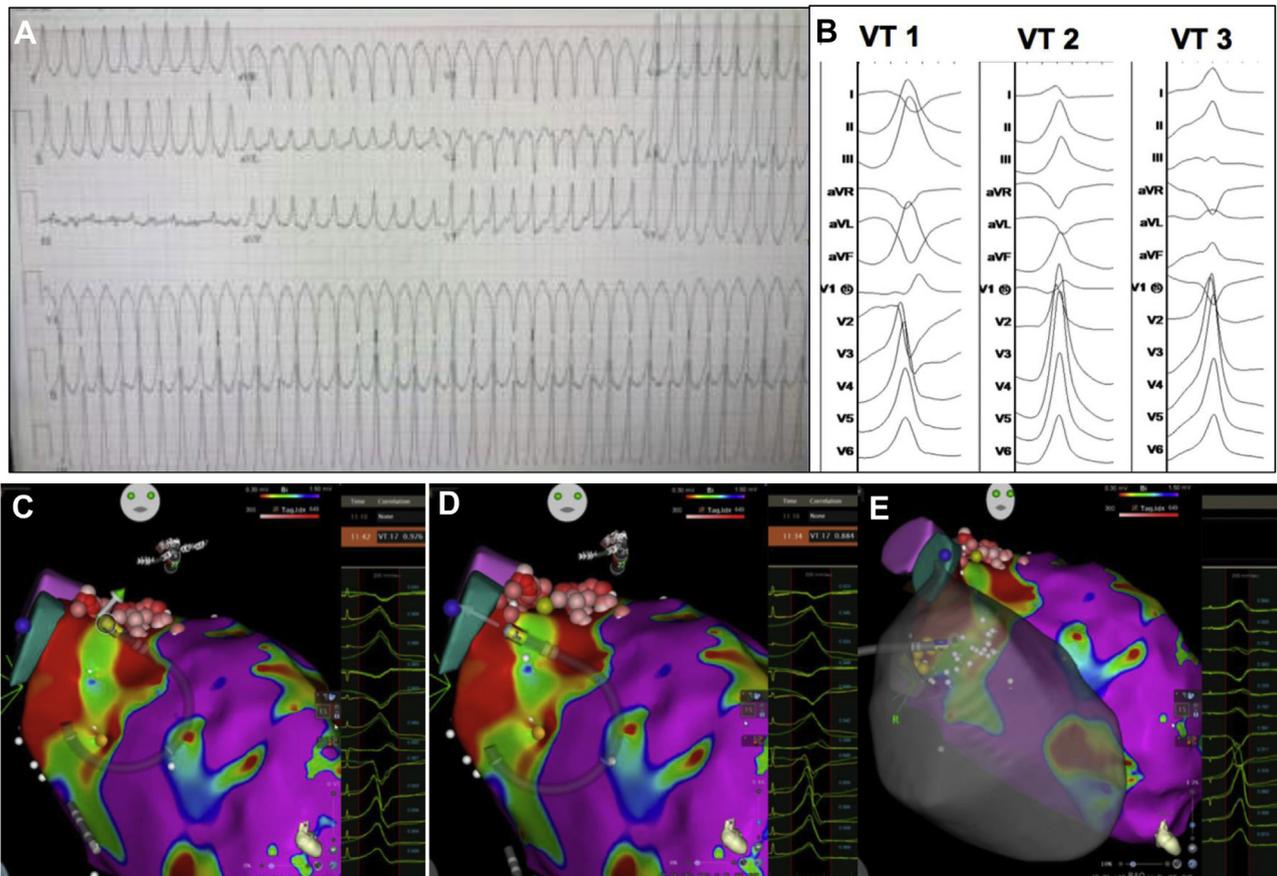


Figure 1 A: Clinical ventricular tachycardia (VT). B: VTs induced during electrophysiology study. C: VT1 pace map-guided ablation. D: VT2 pace map-guided ablation. E: Basal right ventricular septal pace mapping of VT3 near His bundle.

radiofrequency ablation-related heart block, potential inability to reach the suspected intramural site of VT origin, and the patient's refusal to undergo another extensive invasive procedure after his initial 8-hour electrophysiology study / VT ablation, the patient was transferred to our institution and informed consent was provided to proceed with STAR. This procedure was performed for clinical care, without institutional review board approval, using a linear accelerator outside current product labeling.

Materials and methods

A multidisciplinary team of cardiac electrophysiologists, radiation oncologists, and radiation physicists developed a planning target volume (PTV) based upon fusion of 3-dimensional EA maps, cardiac breath hold MRI, and CT simulation following a custom body mold fixation device that placed the patient in the supine "arms up" position without full overhead extension. Once the custom immobilization device was made, a series of CT scans was acquired, including a free-breathing CT and a respiration-correlated CT (4D-CT) with a 2 mm slice interval, which provided information about the sum of cardiac and pulmonary motion. EA maps were merged with DICOM images using custom translational software that converts mesh files to DICOM-RT-compatible files. The EA maps and gadolinium enhanced

cardiac MRI were then fused using in-house software and converted the EA defined target to a DICOM-RT format. The target and MRI set were registered to the simulation CT using MIM Symphony® software (MIMsoftware, Cleveland, OH). Cardiac motion cannot be gated or changed for this therapy, but the septal motion was noted to be less than 3 mm in any direction. Respiratory motion was identified at less than 4 mm; therefore respiratory motion management was managed using a target margin. Anterior, lateral, septal, apical, LV summit, and RV contouring was performed. The gross target volume (GTV) for ablation was confirmed by the electrophysiology, radiation oncology, and radiation physics team during a multidisciplinary contouring consensus session. The final GTV was developed using the EA maps to identify the adjacent cardiac muscular target. An internal target volume was created by expanding the GTV contour in all directions of measured motion distance. Finally, an additional margin of 5 mm was added to the internal target volume region to create a PTV, which accounted for any residual uncertainties in patient setup, motion, and delivery (Figure 2). As described by previous investigators, the PTV was kept below a 200 cc threshold.¹

The STAR treatment plan was generated in a Monaco® (Elekta, Stockholm, Sweden) treatment planning system to

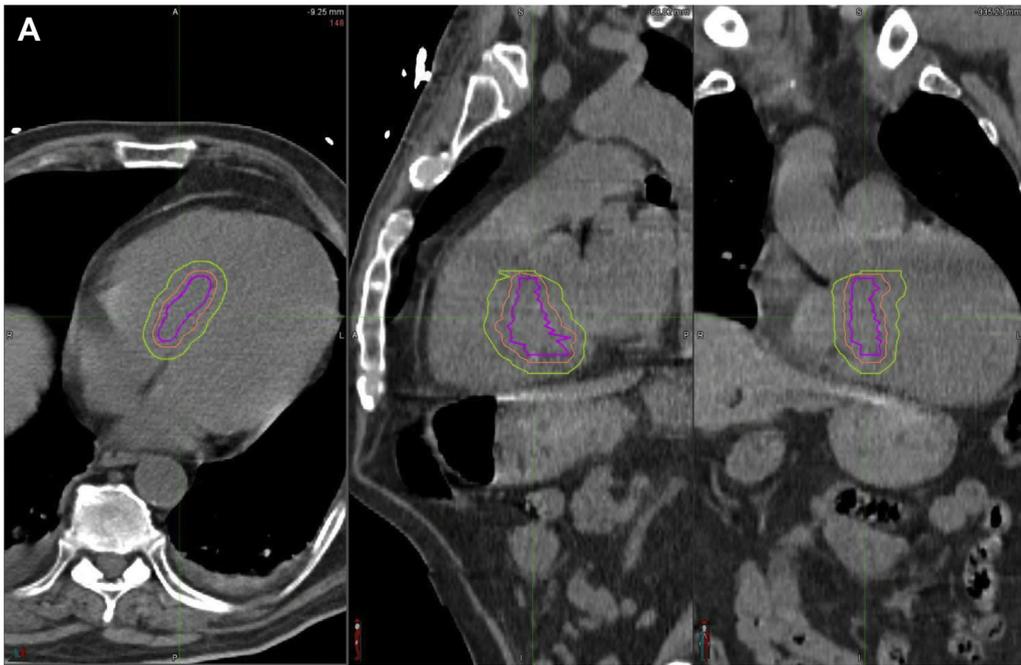


Figure 2 Inner ring (*magenta*): Gross target volume (GTV) of basal interventricular septum based on electroanatomic mapping and magnetic resonance imaging. Middle ring (*orange*): Internal target volume (ITV) = GTV plus cardiorespiratory motion. Outer ring (*green*): Planned target volume (PTV) = ITV plus 5 mm margin and modifications.

deliver a total dose of 25 Gy in a 2-arc single-treatment fraction using dynamic conformal arc therapy to cover the entire region of the PTV using a flattening free filter, allowing for faster dose delivery. The orientation and direction of the radiation beams relative to the patient were selected with the goal of achieving maximal coverage of the PTV region while minimizing the dose to surrounding normal tissue. In addition to these standard radiotherapy principles, the radiation plan was created with the intention of being highly conformal to the target and having a rapid “fall-off” of dose away from the target to spare organs at risk such as the esophagus. Following review and approval of plans in the treatment planning system, all plans were subjected to

standard internal quality assurance to ensure accurate delivery of the dose to the patient prior to treatment delivery. At the time of treatment, the patient was placed in the custom immobilization mold and aligned using a kilovoltage cone beam CT. The planning constraints are listed in [Table 1](#).

Due to presence of baseline bifascicular block and potential risk of recurrent VT and treatment-related atrioventricular (AV) block, a cardiac resynchronization therapy defibrillator device was implanted. The following day, the patient underwent STAR treatment with 25 Gy in single fraction to the interventricular basal septum. AV block was not observed during or after the procedure, which was tolerated well and completed over the course of 20 minutes. Device parameters were stable post therapy. A 12-lead electrocardiogram on post therapy day 1 showed intact AV conduction with unchanged PR interval and QRS morphology from baseline ([Figure 3](#)). Device interrogation at 4 weeks post therapy documented intact AV conduction without any further sustained VT. Sadly, the patient died owing to rapid and unexpected progression of multiple myeloma after his 4-week follow-up. His device was deactivated as part of his hospice plan that was delivered out of our care network, thus limiting longer-term arrhythmia follow-up.

Table 1 Planning constraints

| Parameter | Constraint |
|---------------------------------|--|
| Planning target volume (PTV) | 95% receives 95% of planned dose (23.75 Gy); volume = 62.6 cc |
| Internal target volume (ITV) | 35 Gy maximum point dose |
| Gross target volume (GTV) | 35 Gy maximum point dose; volume = 13.5 cc |
| Spinal cord dose limit | <0.35 cm ³ receives 10 Gy (max point 14 Gy); <1.2 cm ³ receives 8 Gy |
| Esophagus dose limit | <5 cm ³ receives 11.9 Gy (max point 15.4 Gy) |
| Stomach dose limit | <5 cm ³ receives 17.4 Gy (max point dose 22 Gy) |
| Total bilateral lung dose limit | 1500 cm ³ receives 7 Gy max point dose |
| Liver dose limit | ≤700 cm ³ receives 11 Gy max point dose |

Discussion

STAR offers a noninvasive strategy for treatment of refractory VT.² In our case, STAR offered a palliative option for recurrent, symptomatic, intramural VT originating from the interventricular basal septum without adverse effects to

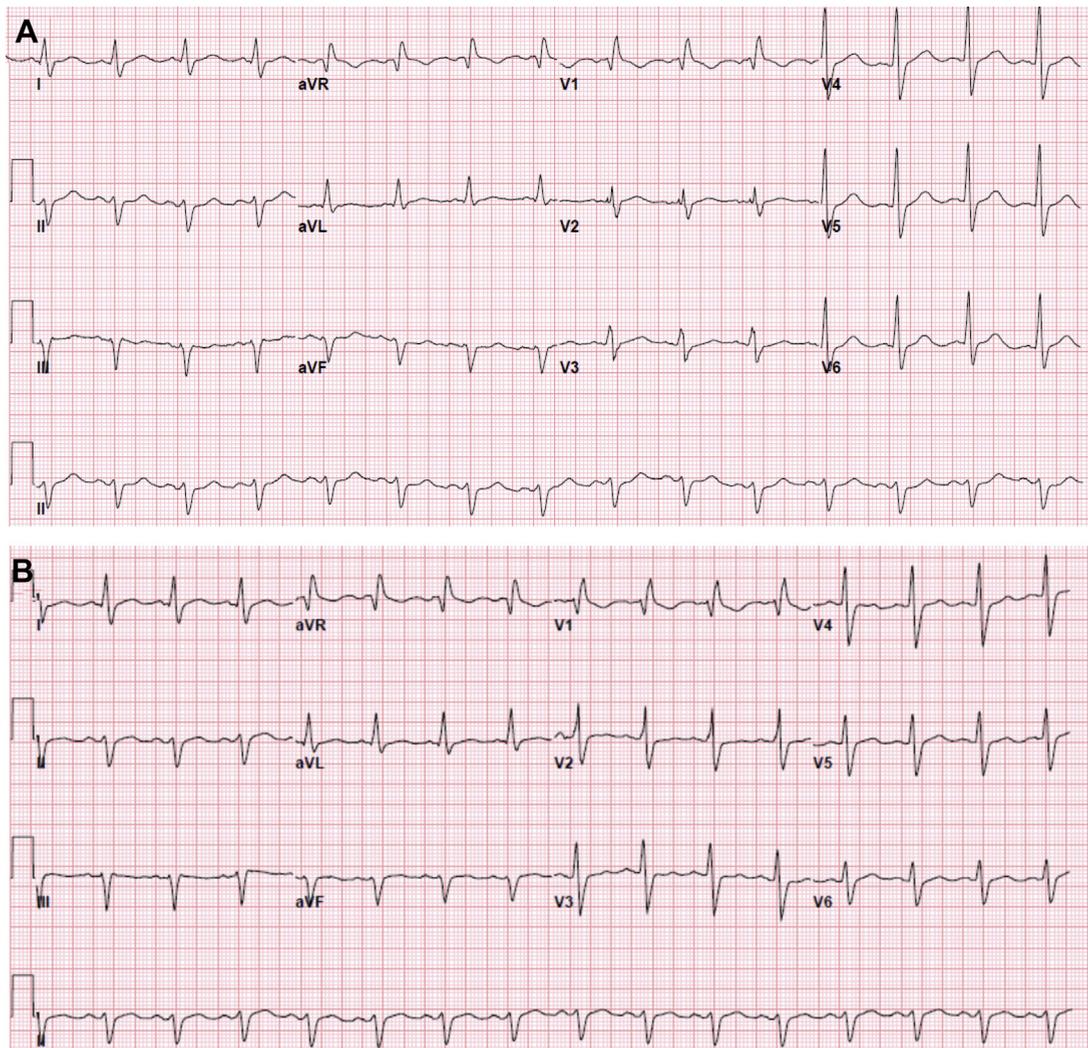


Figure 3 A: Preprocedure electrocardiogram (ECG) with baseline right bundle and left anterior hemiblock. B: Unchanged ECG 24 hours after STAR therapy.

a newly implanted cardiac resynchronization therapy defibrillator device or apparent damage to the His-Purkinje system. Our findings are similar to those reported in a prospective clinical trial, in which AV block has not been observed following radioablation for VT.³ While unipolar and bipolar RF ablation strategies have been described to treat septal intramural VTs,⁴⁻⁸ we decided against these options owing to concerns about RF-related heart block and potentially ineffective VT suppression. Furthermore, our patient strongly favored a noninvasive approach following his initial extensive procedure.

The incorporation of EA mapping during STAR planning, in addition to cardiac MRI and CT, potentially allows for greater accuracy of radiation delivery to the suspected site of VT origin. Preprocedure planning by a multidisciplinary team of cardiac electrophysiologists, cardiac imaging specialists, radiation oncologists, and radiation physicists was critical to ensuring maximal accuracy of target volume treatment and minimizing potential radiation-related effects

to surrounding structures. Our patient's experience was positive in that his procedure was painless and completed in 20 minutes after extensive planning. He remained free of recurrent, sustained VT with intact AV conduction 1 month after therapy before dying owing to unexpected progression of multiple myeloma.

Conclusions

STAR therapy may offer an effective, noninvasive option for treatment of intramural VT originating near the His bundle without conduction system damage. Despite efforts to minimize registration errors, we recognize inherent errors when registering imaging modalities acquired from different phases of cardiac and respiratory motion, different axes, and different physical positions. Overcoming these errors promises greater accuracy for targeting arrhythmic substrate. Longer follow-up is required to determine the true safety, conduction system effects, and efficacy of this therapy.

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