Integration of electroanatomical mapping with imaging to guide radiotherapy of VT substrates with high accuracy

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VOL. 6, NO. 7, 2020
ISSN 2405-500X/$36.00

Letters

RESEARCH CORRESPONDENCE

Integration of Electroanatomical Mapping With Imaging to Guide Radiotherapy of VT Substrates With High Accuracy

Radiofrequency catheter ablation (CA) of ventricular tachycardia (VT) in nonischemic cardiomyopathy is challenging. In particular, the left ventricular (LV) summit can be inaccessible because of the proximity of the coronary arteries and a thick epicardial fat layer (1). Stereotactic body radiotherapy (SBRT), a technology commonly used to treat tumors, is an emerging technique for treating VT, overcoming potential limitations of specific substrate locations. SBRT requires accurate substrate delineation and delivery of high-dose radiation with high precision (2). Previous studies have used electrocardiographic imaging (ECGi) to determine the VT exit and have targeted the full myocardial thickness of the associated scar at this site by SBRT (3). However, ECGi is hampered by only moderate accuracy, and the distance between the critical VT substrate and earliest epicardial activation can exceed several centimeters (4). More accurate target volume delineation is desirable. Here, we report our initial experience with real-time integration of electroanatomical substrate mapping (EAM) with imaging and reversed integration allowing for accurate gross target volume (GTV) delineation, repeated adjustment, and final confirmation.

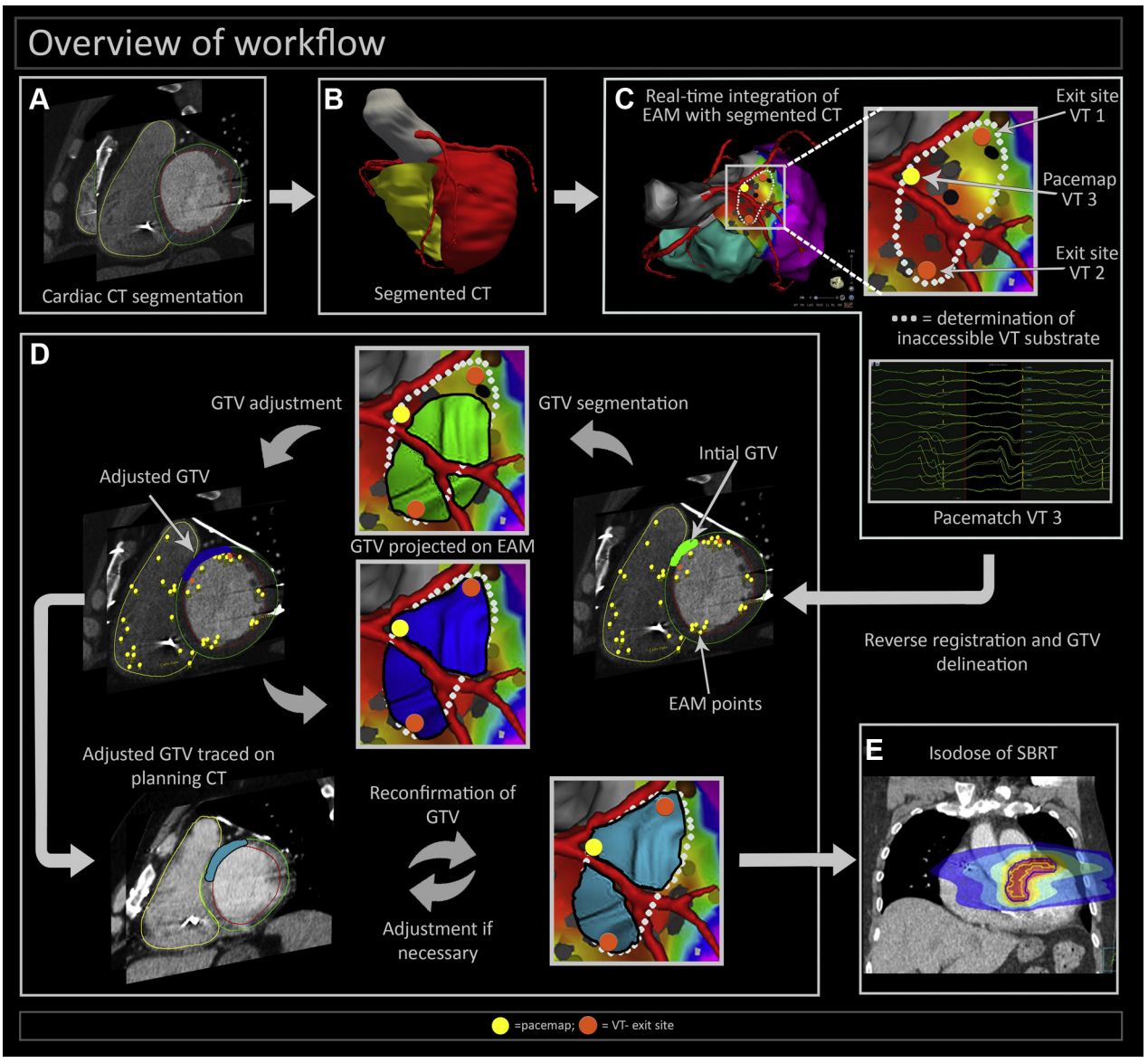
Two patients (Patient #1: female, 72 years of age, dilated cardiomyopathy, ejection fraction 28%; Patient #2: male, 51 years of age, hypertrophic cardiomyopathy, ejection fraction 44%) admitted with drug-refractory VTs from the anteroseptal LV and ≥3 prior CAs (including endoepicardial CA with extracorporeal membrane oxygenation support and surgical ablation) were treated with SBRT after CA failure. Both patients were discussed in a multidisciplinary team. Patient #1 was rejected for LV assist device (LVAD) as destination therapy because of incessant VT, and Patient #2 was accepted for heart transplantation but with an anticipated long waiting time.

During the last nonsuccessful CA, the routinely performed pre-procedural ECG-gated computed tomography (CT) was segmented into 3-dimensional (3D) anatomical structures (MASS version 2019-EXP, Division of Image Processing [LKEB], Leiden University Medical Center, Leiden, the Netherlands) and real time integrated with the high-density LV electroanatomical substrate map (CARTO 3, version 6.0.54.11, Biosense Webster, Diamond Bar, California) using the left main artery as landmark and the endocardial surfaces (**Figures 1A to 1C**). Detailed pace mapping and limited activation mapping were performed to accurately determine the VT substrate inaccessible by CA. All pace-match and re-entry circuit sites consistent with VT exit sites and unexcitable scar sites were tagged on the map (**Figure 1C**). EAM data, including the 3D coordinates of the tagged points, were extracted and projected on the CT (reversed registration) (**Figure 1D**). Based on the 3D coordinates of all VT related sites, the GTV was created from multiple CT projections. The GTV was segmented and reintegrated into the mapping system to confirm that all VT-related sites were located within the GTV (first confirmation). If required, the GTV dimensions could be adjusted and reintegrated with the EAM data (reconfirmation) (**Figure 1D**).

Before radiotherapy, an additional respiratory-gated 4-dimensional (4D) CT consisting of 10 phases was performed (4D planning CT) to measure intrathoracic intrafraction movement of the target (2). The adjusted GTV was transferred from the ECG-gated CT to the 4D-CT by tracing the target area using exactly the same CT projection (**Figure 1D**). Next, the 4D-CT with the traced GTV was segmented and reverse-integrated into EAM system using the endocardial contours and the left main artery to confirm that the GTV on the 4D-CT contained the VT substrate. To compensate for internal motion caused by breathing and cardiac motion, an internal target volume was created, covering the GTV in all phases. Finally, to account for patient setup and beam delivery errors, an isotropic planning target volume (PTV) (margin 5 mm) was calculated and created.

The PTV was targeted with a single fraction, online cone-beam CT-guided SBRT of 25 Gy using a conventional linear accelerator with GTV of 24 and 35 cm^3 and PTV of 85 and 100 cm^3, respectively. Patients were discharged on the same medication 5 and 6 days after SBRT, respectively. Patient #1

FIGURE 1 **SBRT Guided by Integration and Reversed Registration of Substrate Mapping and Imaging**



(A) Cardiac CT segmentation. **(B)** 3D anatomical reconstruction. **(C) upper left:** real-time image integration; **upper right:** determination of VT substrate location; **lower right:** example of pace-match for VT 3. **(D)** GTV creation and confirmation. **(E)** Isodose distribution of SBRT. CT = computed tomography; EAM = electroanatomical substrate mapping; GTV = gross target volume; SBRT = stereotactic body radiotherapy; VT = ventricular tachycardia.

experienced a slow VT, terminated by anti-tachycardia pacing, 43 days after LVAD (184 days after SBRT), probably related to the LVAD cannula. During 277 and 181 days of follow-up in patients 1 and 2, respectively, no acute or late toxicity of SBRT was observed and no recurrence of the targeted VT was documented.

To the best of our knowledge, this is the first report of EAM-guided SBRT using real-time image integration and reversed registration for accurate VT substrate delineation. The suggested method allows repeated adjustment and confirmation of the GTV to accurately target the VT substrate, which may translate into improved outcome and potentially minimalizes collateral damage. However, long-term effects and safety are still unknown, and in our opinion, SBRT should be currently reserved as bailout procedure after standard treatments have failed.

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https://doi.org/10.1016/j.jacep.2020.03.014

Please note: The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the *JACC: Clinical Electrophysiology* author instructions page.

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RESEARCH CORRESPONDENCE

Multielectrode Mapping Versus Point-by-Point Mapping for Catheter Ablation of Ventricular Tachycardia

A Systematic Review and Meta-Analysis

Ventricular tachycardia (VT) substrate delineation is important for successful catheter ablation. Newer multielectrode mapping (MEM) technologies can construct higher density maps than can traditional point-by-point (PBP) mapping but are expensive and lack contact force-sensing capabilities. Although there are no large-scale randomized controlled trials (RCTs) comparing MEM versus PBP mapping, MEM has become widely used in VT ablation. This meta-analysis was performed to assess the impact of MEM versus PBP substrate mapping on ablation outcomes.

This study was performed according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) criteria. PubMed, Embase, Medline, and EmCare were electronically searched for studies comparing MEM and PBP mapping for VT ablation. Search terms were "Ventricular Tachycardia" AND ("multi electrode" OR "multisite" OR "high density" OR "Pentaray" OR "High Density Grid" OR "Duodecapolar" OR "Orion" OR "Point by Point"). Studies were included if they reported head to head procedural outcomes (acute procedural success or VT recurrence at 12 months). Acute procedural success was defined as noninducibility of VT at completion of procedure determined by programmed ventricular stimulation. Secondary outcomes included mapping, ablation ,and total procedural durations. Relative risk (RR) or mean difference (MD) was used as the summary statistic, and is reported with 95% confidence interval (CI). For VT recurrence, adjusted or propensity-matched ratios were preferentially extracted if available. Meta-analyses were performed using random-effects models. All statistical analysis was performed using Review Manager version 5.3 (Cochrane Collaboration, London, United Kingdom). Ethics approval was not required as this was a meta-analysis.

Four of 1,323 identified papers met the inclusion criteria. One was a pilot RCT (1) and the rest were observational studies (2–4). Studies that did not report on procedural success or VT recurrence were excluded (5), as were duplicate reports (6). A total of 321 VT ablations (MEM: n = 168; PBP mapping: n = 153) in 300 patients (average 64 years of age) for both ischemic and nonischemic cardiomyopathy were included. The multielectrode catheter used in all of the studies was the PentaRay catheter (Biosense Webster, La Jolla, California).

There was no difference in acute procedural success between MEM and PBP mapping (RR: 0.95; 95% CI: 0.80 to 1.12; $I^2 = 0\%$; p = 0.53) (**Figure 1A**). There was a trend toward reduction of VT recurrence at 12 months (RR: 0.80; 95% CI: 0.61 to 1.05; $I^2 = 0\%$; p = 0.11) (**Figure 1B**). In Maagh et al. (2), MEM patients were more likely to have had previous VT ablations (50% vs. 27%), poorer left ventricular ejection fraction (28.2% vs. 39.5%), and treatment with amiodarone (42.3% vs. 18.8%) (3). Excluding this study, the RR for VT recurrence rate was 0.75 (95% CI: 0.56 to 1.01; $I^2 = 0\%$; p = 0.06).