JACC: CLINICAL ELECTROPHYSIOLOGY
VOL. 2, NO. 4, 2016

ISSN 2405-500X/$36.00
PUBLISHED BY ELSEVIER
http://dx.doi.org/10.1016/j.jacep.2016.01.013

NEW RESEARCH PAPERS

Simultaneous Amplitude Frequency Electrogram Transformation (SAFE-T) Mapping to Identify Ventricular Tachycardia Arrhythmogenic Potentials in Sinus Rhythm

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ABSTRACT

OBJECTIVES This study sought to develop a novel automated technique, simultaneous amplitude frequency electrogram transformation (SAFE-T), to identify ventricular tachycardia (VT) isthmuses by analysis of sinus rhythm arrhythmogenic potentials (AP).

BACKGROUND Substrate ablation is useful for patients with scar-related hemodynamically unstable VT; however, the accuracy of different approaches remains inadequate, varying from targeting late potentials to full scar homogenization.

METHODS High-density ventricular mapping was performed in 3 groups: 1) 18 normal heart control subjects; 2) 10 ischemic patients; and 3) 8 nonischemic VT patients. In VT patients, isthmus sites were characterized using entrainment responses. Sinus rhythm right ventricle/left ventricle endocardial and epicardial electrograms underwent Hilbert-Huang spectral analysis and were displayed as 3-dimensional SAFE-T maps. AP and their relation to the VT isthmus sites were studied.

RESULTS AP were defined by a cutoff value of 3.08 Hz mV using normal heart control subjects. Receiver-operating characteristics showed that VT isthmus sites were best identified using SAFE-T mapping ($p < 0.001$) as compared with bipolar and unipolar scar and late potential mapping with an optimal cutoff value of 3.09 Hz mV, allowing identification of 100% of the 34 mapped VT isthmuses, compared with 68% using late potentials. There was no significant difference between sinus rhythm and paced SAFE-T values. Abnormal SAFE-T areas involved about one-quarter of the scar total area.

CONCLUSIONS Automated electrogram analysis using 3-dimensional SAFE-T mapping allows rapid and objective identification of AP that reliably detect VT isthmuses. The results suggest that SAFE-T mapping is good alternative strategy to late potential mapping in identifying VT isthmuses and allows reduced ablation as compared to scar homogenization. (J Am Coll Cardiol EP 2016;2:459–70) © 2016 by the American College of Cardiology Foundation.

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This work was supported by Ministry of Science and Technology of Taiwan for National Yang-Ming University, Taipei Veterans General Hospital, and the Center for Dynamical Biomarkers and Translational Medicine, National Central University (MOST 103-2221-E-008-006-MY3, 103-2314-B-010-048-MY3, 103-2321-B-008-003, 104-3115-E-008-001, 104-2314-B-010-063-MY2); Grant of Taipei Veterans General Hospital (V104E7-001, V105C-122).

Manuscript received October 2, 2015; revised manuscript received January 21, 2016, accepted January 26, 2016.

JACC: CLINICAL ELECTROPHYSIOLOGY VOL. 2, NO. 4, 2016
AUGUST 2016:459–70

ABBREVIATIONS AND ACRONYMS

3D = 3-dimensional

AP = arrhythmogenic potential(s)

EAM = electroanatomic map(ping)

HHT = Hilbert-Huang transform

LV = left ventricle

LVZ = low-voltage zone

RFCA = radiofrequency catheter ablation

RV = right ventricle

SAFE-T = simultaneous amplitude frequency electrogram transformation

SR = sinus rhythm

VT = ventricular tachycardia

Radiofrequency catheter ablation (RFCA) is an effective treatment option in post-infarction or nonischemic cardiomyopathy patients with medically refractory ventricular tachycardia (VT) (1). Substrate ablation techniques are preferred in patients with VT due to hemodynamic instability and require a thorough point-by point acquisition of voltage information displayed on a 3-dimensional (3D) electroanatomic map (EAM). Abnormal voltage cutoff values are established and reflect damaged myocardial tissue or scar (2). High-density 3D pace-mapping, the presence of arrhythmogenic potentials (AP) (3,4), and cardiac magnetic resonance scar characteristics are techniques that enable VT isthmus identification without the need for activation and entrainment mapping (5-7). Of these, the targeting of AP during sinus rhythm (SR) in patients with scar-related VT has been most widely utilized (2,4,8,9). The classical procedural endpoint is abolition of inducible VT, targeting either the clinical VT or all inducible VT (10,11). Recent studies have demonstrated that the additional targeting of AP during SR is associated with reduced VT recurrence in patients with ischemic and nonischemic VT (8,9,11,12). Local and distant pacing maneuvers are used to demonstrate a long stimulus-to-QRS interval or multicomponent electrograms, indicative of poorly coupled myocardium; however, this is impractical in the setting of scar with hundreds of potential sites (8,11).

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We propose a novel automated temporal frequency analysis method using the Hilbert-Huang transform (HHT) (13), interpreted within the 3D EAM, to accurately recognize AP during SR that colocate with VT isthmuses characterized by classical entrainment mapping.

METHODS

STUDY POPULATION. From 2013 to 2015, 18 consecutive patients referred to our center for VT ablation, who underwent a detailed electrophysiological study using the CARTO 3 system (MEM version, UDM Module, Biosense Webster, South Diamond Bar, California) and had isthmus identification through entrainment of tolerated VT and successful isthmus-directed RFCA, were recruited. All patients had episodes of repetitive, sustained VT resistant to antiarrhythmic medication requiring external cardioversion or implantable cardioverter-defibrillator therapies. Baseline characteristics were assessed in detail. All patients provided written informed consent prior to participation. The procedures were all clinically indicated, and the human research committee approved data collection.

ELECTROANATOMIC SUBSTRATE MAPPING. A standardized electrophysiological study was performed in the fasting state with conscious sedation or general anesthesia. Antiarrhythmic drugs were discontinued for a minimum of 5 half-lives before RFCA. In the absence of spontaneous VT, rapid ventricular pacing and programmed stimulation with up to 3 extra stimuli was performed with a catheter placed at the right ventricular (RV) apex. If VT was noninducible, intravenous isoprenaline 1 to 5 μg/min was infused to achieve at least 20% heart rate increment.

The VT QRS morphologies were compared with those of the documented VT. The left ventricular (LV) endocardium was accessed by transseptal or retrograde transaortic approach. Pericardial access was obtained by subxiphoid puncture if a previous endocardial ablation had failed, if an epicardial substrate was suspected, or if minimal or no endocardial scar was present. EAM was performed during SR using CARTO system. Mapping and RFCA were performed with an open-irrigated ablation catheter (Thermocool, Biosense Webster). The voltage maps were edited by manually eliminating intracavitary points. To avoid low-voltage recordings due to poor contact, the following criteria were used: 1) the signal had to satisfy 3 stability criteria automatically detected by the CARTO system in terms of cycle length, local activation time, and beat-to-beat difference of the location of the catheter; 2) both bipolar and unipolar signals were simultaneously acquired to confirm true catheter contact through the analysis of the local electrogram; and 3) in the presence of a low-voltage area, at least 3 additional points were acquired in the same site to confirm the reproducibility of the voltage measurement. Unipolar filtering was set at 2 to 240 Hz, and bipolar filtering set at 16 to 500 Hz. Wilson central terminal was assigned as the unipolar reference electrode. Intracardiac bipolar electrogram data were exported through the Carto UDM Module for HHT transformation. The products were reimported to Carto UDM Module for real-time analysis ensuring anatomic coregistration. Bipolar scar and low-voltage areas were defined as areas with a peak-to peak bipolar voltage <0.5 and <1.5 mV, RV and LV unipolar scar area as areas with a peak-to-peak unipolar voltage <5.5 and <8.3 mV, respectively (2). Late potentials were defined as local ventricular potentials occurring after the terminal portion of the surface QRS, whereas early arrhythmogenic