Twelve-lead electrocardiographic characteristics of the aortic cusp region guided by intracardiac echocardiography and electroanatomic mapping

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BACKGROUND The most common site of origin of idiopathic ventricular tachycardia (VT) is the right ventricular outflow tract. Idiopathic VT also can arise from the left ventricular outflow tract and the surrounding structures. Morphologic descriptions of 12-lead ECG characteristics of the aortic cusp region are limited.

OBJECTIVE The purpose of this study was to define unique ECG characteristics of the aortic cusp region by performing a systematic analysis of pacemapping of this region in patients with structurally normal hearts.

METHODS A combination of electroanatomic mapping, intracardiac echocardiography, and fluoroscopic guidance was used to study a total of 30 patients with structurally normal hearts undergoing left-sided ablation procedures. Each of the aortic valve cusps and the aortomitral continuity were paced at threshold and analyzed offline to determine unique ECG characteristics.

RESULTS Pacing from the left coronary cusp typically produced a multiphasic QRS morphology consistent with an M or W pattern in lead V_1 with a precordial transition (R>S) no later than V_2. Pacing from the right coronary cusp typically resulted in a left bundle-type pattern with a broad small R wave in V_2 and a precordial transition generally at V_3. Pacing from the aortomitral continuity resulted in a qR pattern that was not observed anywhere else in the left ventricular outflow tract. When comparing the right coronary cusp and left coronary cusp, the precordial transition was earlier in the left coronary cusp than in the right coronary cusp. Pacing the noncoronary cusp uniformly resulted in atrial capture.

CONCLUSION When considering ablation of idiopathic VT, the aortic cusps and aortomitral continuity must be considered as possible foci. The 12-lead ECG, a readily and easily obtainable source of information, has useful characteristics for differentiating VTs arising from the cusp region.

KEYWORDS Aortic cusp; Ventricular tachycardia; Intracardiac echocardiography; Electrocardiography

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Introduction/background

The majority of idiopathic ventricular tachycardia (VT) originates from the right ventricular outflow tract (RVOT), just inferior to the pulmonic valve, and is amenable to catheter ablation with high success.[1,2] Tachycardia arising from sites above the pulmonary valve has also been reported.[3] Less commonly, idiopathic VTs can arise from the outflow tract of the left ventricle and surrounding regions.[4,5] Limited descriptions of the 12-lead ECG morphology of VT arising from the outflow tract regions have been published.[4–8] Due to the focal nature of most outflow tract VTs, the usefulness of the surface ECG in this setting for localizing the site of origin is helpful. However, a systematic analysis of the 12-lead ECG characteristic of pacing from this region has not been fully described in a larger cohort of patients with structurally normal hearts. ECG characteristics that help to localize the site of origin of these tachycardias prior to ablation may assist with preprocedural planning and potentially improve ablation outcome. In this study, we sought to identify unique ECG characteristics by pacing at each of the aortic valve cusps and the aortomitral continuity in patients with structurally normal hearts who referred for ablation procedures.

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Methods

Magnetic electroanatomic mapping, intracardiac echocardiography, and fluoroscopic guidance were used to define the aortic valve cusps and the surrounding region. A total of 30 patients referred to the University of Pennsylvania Health System for any left-sided ablations were included in the study. Only patients with structurally normal hearts, defined by a normal nuclear perfusion scan, normal echocardiogram, and/or normal coronary angiography, were included in this series. All patients had at least a normal perfusion scan and echocardiogram. Cardiac catheterization was per-

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formed due to equivocal perfusion scans in four patients who had normal coronary angiograms. Patients were brought to the electrophysiology laboratory in the postabsorptive, nonsedated, drug-free state after written informed consent had been obtained in conjunction with the University of Pennsylvania Health System's institutional guidelines.

Pacemapping protocol

Surface ECG leads were applied in the standard manner. Multipolar electrode catheters were introduced percutaneously via the femoral vein and artery and, in some cases, the internal jugular veins, depending on the planned ablation procedure. Because all patients had no structural heart disease, the majority were undergoing ablation of a left-sided accessory pathway, left-sided atrial tachycardia, or idiopathic VT ablation. Catheters were positioned in the right atrium, right ventricle, and His-bundle region. A 4-mm mapping/ablation catheter was advanced to the aorta in retrograde fashion via an 8Fr femoral arterial sheath. Three-dimensional electromagnetic mapping (CARTO, Biosense Webster, Diamond Bar, CA, USA) of the left ventricular outflow tract (LVOT) and the basal left ventricle was performed (Figure 1). Pacemapping was performed at the right coronary cusp (RCC), left coronary cusp (LCC), and aortomitral continuity (AMC). The noncoronary cusp also was identified and mapped. Sites were identified and tagged using magnetic electroanatomic mapping, and accurate localization of pacemapping sites was confirmed by biplane fluoroscopy and intracardiac echocardiography (Figures 2 through 4). Each pacemap site was labeled on the electroanatomic mapping system, and bipolar pacing was performed at threshold to minimize capture of surrounding tissue. The surface ECG was recorded using the Prucka CardioLab EP recording system (General Electric, Houston, TX, USA).

ECG analysis

The 12-lead ECG was recorded at a sweep speed of 100 ms at each of the anatomic sites of interest and then analyzed offline. Pacemapped ventricular beats were analyzed with respect to QRS morphology, amplitude, duration, and precordial vector transition (Figures 5 and 6).

Statistical analysis

Values are reported as mean ± SD. Continuous variables were compared using Student's t-test. Characteristics of the RCC, LCC, and AMC were compared using analysis of variance (ANOVA) to assess the overall difference between groups. Bonferroni correction was used to correct for multiple comparisons within groups. $P \leq .05$ was considered significant.

Results

Patient characteristics

Mean age of the study cohort was 45 ± 15 years. The majority of patients were male (21/30). Left ventricular systolic ejection fraction (LVEF) ranged from 50% to 75% (median 60%). The aortic valve was normal in all patients as determined by echocardiography. Patients with coronary artery disease with prior myocardial infarctions were not included in this cohort of patients.

Pacemapping analysis

A total of 85 pacemaps from 30 patients were analyzed. Pacemapping of all cusp sites, including the AMC, was performed in 14 (46.7%) of 30 patients; of three sites in 11 (36.6%) patients; and of two sites in the remaining 5 (16.7%) patients. A total of 24 LCC, 24 RCC, 22 noncoronary cusp, and 15 AMC pacemapping sites were completed and analyzed offline after confirmation of quality tracings.

QRS axis and precordial transition

Pacing from the aortic cusp region and AMC uniformly resulted in an inferiorly directed axis as expected, given their anatomic locations.

Pacing from the LCC typically produced a multiphasic QRS morphology consistent with an M- or W-shaped pattern

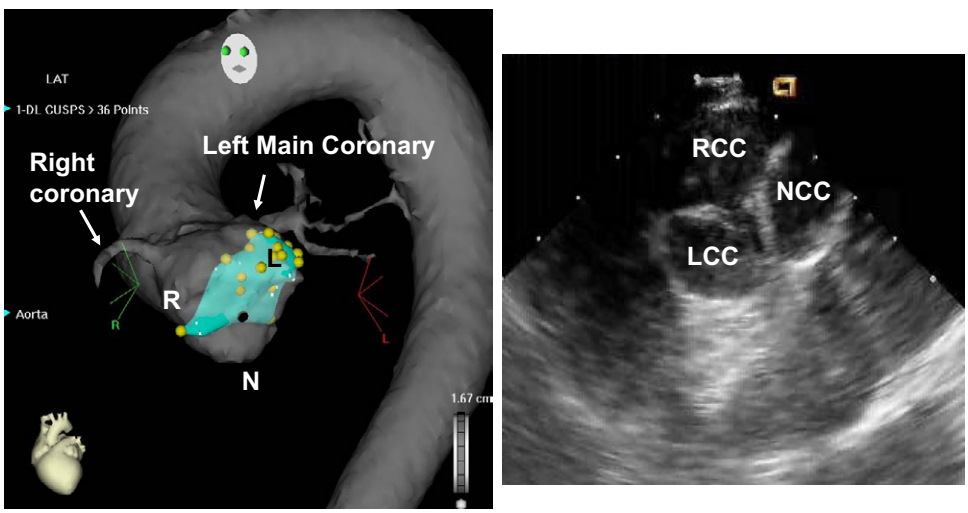

Figure 1 **Left:** CARTO merge figure showing detailed mapping of the aortic cusp region and the typical anatomic locations of each valve relative to the coronary arteries. (L = left coronary cusp; N = noncoronary cusp; R = right coronary cusp). **Right:** Corresponding intracardiac echocardiographic image depicting the three cusps of the aortic valve. LCC = left coronary cusp; NCC = noncoronary cusp; RCC = right coronary cusp.