Noninvasive electrocardiographic mapping to guide ablation of outflow tract ventricular arrhythmias

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BACKGROUND Localizing the origin of outflow tract ventricular tachycardias (OTVT) is hindered by lack of accuracy of electrocardiographic (ECG) algorithms and infrequent spontaneous premature ventricular complexes (PVCs) during electrophysiological studies.

OBJECTIVES To prospectively assess the performance of noninvasive electrocardiographic mapping (ECM) in the pre-/periprocedural localization of OTVT origin to guide ablation and to compare the accuracy of ECM with that of published ECG algorithms.

METHODS Patients with symptomatic OTVT/PVCs undergoing clinically indicated ablation were recruited. The OTVT/PVC origin was mapped preprocedurally by using ECM, and 3 published ECG algorithms were applied to the 12-lead ECG by 3 blinded electrophysiologists. Ablation was guided by using ECM. The OTVT/PVC origin was defined as the site where ablation caused arrhythmia suppression. Acute success was defined as abolition of ectopy after ablation. Medium-term success was defined as the abolition of symptoms and reduction of PVC to less than 1000 per day documented on Holter monitoring within 6 months.

RESULTS In 24 patients (mean age 50 ± 18 years) recruited ECM successfully identified OTVT/PVC origin in 23/24 (96%) (right ventricular outflow tract, 18; left ventricular outflow tract, 6), sublocalizing correctly in 100% of this cohort. Acute ablation success was achieved in 100% of the cases with medium-term success in 22 of 24 patients. PVC burden reduced from 21,837 ± 23,241 to 1143 ± 4039 ($P < .0001$). ECG algorithms identified the correct chamber of origin in 50%–88% of the patients and sublocalized within the right ventricular outflow tract (septum vs free-wall) in 37%–58%.

CONCLUSIONS ECM can accurately identify OTVT/PVC origin in the left and the right ventricle pre- and periprocedurally to guide catheter ablation with an accuracy superior to that of published ECG algorithms.

KEYWORDS Ventricular tachycardia; Premature ventricular complex; Outflow tract tachycardia

ABBREVIATIONS **CT** = computed tomographic; **EF** = ejection fraction; **ECG** = electrocardiographic; **ECM** = electrocardiographic mapping; **EPS** = electrophysiological study; **LV** = left ventricular/ventricle; **LVOT** = left ventricular outflow tract; **OTVT** = outflow tract ventricular tachycardia; **PVC** = premature ventricular complex; **PVS** = programmed ventricular stimulation; **RV** = right ventricular/ventricle; **RVOT** = right ventricular outflow tract; **VT** = ventricular tachycardia

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Introduction

Outflow tract ventricular tachycardia (OTVT) or frequent premature ventricular complexes (PVCs) often occur in the absence of structural heart disease and account for 10% of all ventricular tachycardia (VT).[1,2] The majority of these originate from the right ventricular outflow tract (RVOT) and the remainder from the left ventricular outflow tract (LVOT), including the cusps of the aortic valve.[3] Catheter ablation within these complex anatomical structures can be effective in eliminating symptoms and reversing PVC-induced cardiomyopathy, but there remain significant limitations to current mapping techniques, including poor spatial resolution of pace mapping, inaccurate localization of VT origin based on electrocardiographic (ECG) algorithms, and, especially limiting, lack of spontaneous ectopy rendering activation mapping ineffective.[4–6]

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Body surface electrocardiographic mapping (ECM) is a noninvasive technique providing global electroanatomical maps of both ventricular chambers by projecting 252 body surface electrode signals onto the epicardial geometry of the heart derived from a noncontrast thoracic computed tomographic (CT) scan.[7] This technology has the advantage of being able to display the onset and electrical propagation of a single PVC, recorded preprocedurally, onto the biventricular geometry to guide ablation.

The objectives of this prospective study are 2-fold: first, to compare the accuracy of noninvasive ECM with that of validated ECG algorithms in localizing OTVT origin preprocedurally, and second, to assess the periprocedural capabilities of ECM as a novel mapping tool to guide ablation of OTVT.

Methods

Study population

Patients undergoing clinically indicated ablation for symptomatic PVCs or asymptomatic but frequent (≥10,000/24 h) PVCs with an inferior axis on the 12-lead ECG were prospectively recruited into the study. In addition, patients with asymptomatic and/or infrequent PVCs in the presence of idiopathic globally impaired left ventricular (LV) function were included. All patients gave written informed consent before the procedure. Local research ethics committee approval was granted for the study.

Preprocedural mapping using ECM

Antiarrhythmic drugs were discontinued at least 5 half-lives before the procedure. The ECM system has been described previously.[7–9] Briefly, it consists of a 252-electrode vest applied to the patient's torso, acquiring electrical data at 2 kHz. After vest application, patients undergo noncontrast thoracic CT scans with an axial resolution of 3 mm. The 252 body surface electrodes and epicardial surface geometry are spatially labeled and defined from CT images. These body surface signals and geometric data are integrated to construct 3-dimensional electroanatomical maps composed of more than 1500 unipolar epicardial signals. These data are then applied to an algorithm to localize the origin of ectopy (Figure 1A). Following the CT scan, patients can ambulate with the vests, which, in our study, were applied from up to 5 hours before the procedure until the ablation was completed. ECM mapping was performed with the patient in a recumbent position.

Three types of electroanatomical maps are generated by ECM: potential, activation, and voltage maps (Figures 1 and 2).

The potential map is a dynamic map that displays global propagation of the depolarization wave front, detected by the earliest QS over the chosen cardiac interval (Figure 1B and Online Supplemental Video 1).

The activation map is a static map displaying the activation sequence across a chosen cardiac interval. The map assigns an activation time to each unipolar electrogram on the epicardial geometry (Figure 2). Activation calculations are computed from both the signal's maximum negative change of voltage (−dV/dT) and the signal morphology of neighboring electrograms. The activation sequence is represented on the map by the color red as early

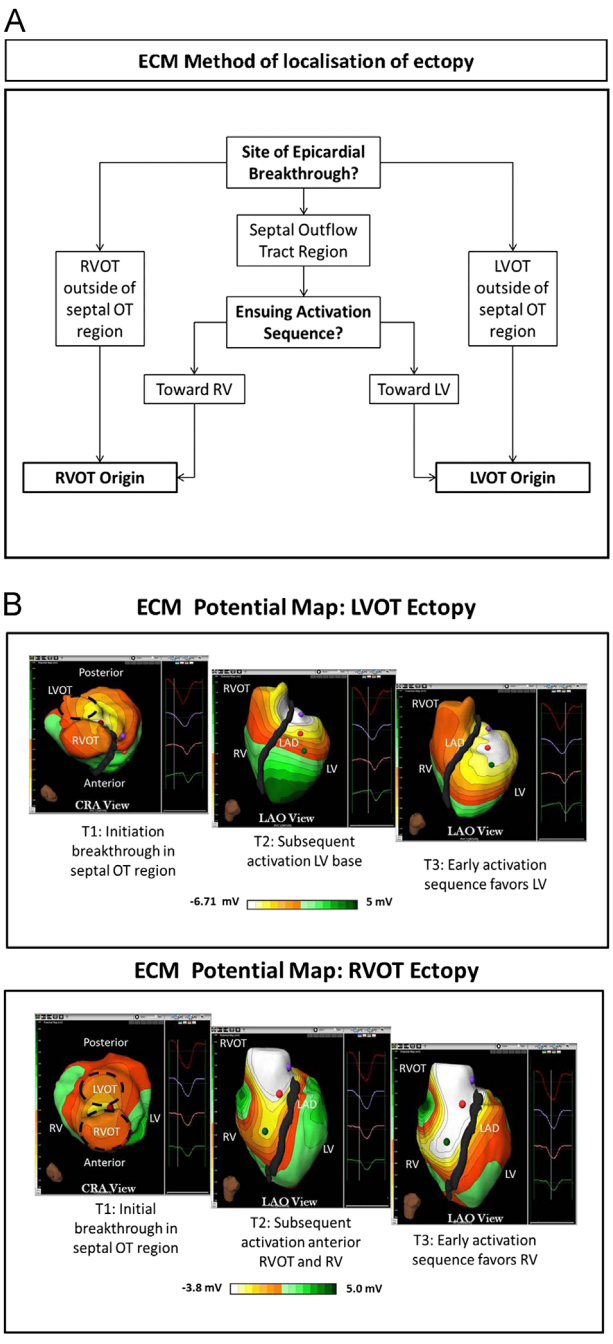

Figure 1 **A:** ECM method of localization of ectopy origin. **B:** ECM potential maps of RVOT and LVOT ectopy. The images show the ECM potential PVC map from the cranial and LAO views at 3 time points: T1, initiation of epicardial breakthrough, and 2 later time points (T2 and T3). Top: After epicardial breakout in the septal groove, the ensuing activation spreads directly anteriorly toward the RV, suggesting RVOT origin. The successful ablation site here was in the mid-septal RVOT. Bottom: After epicardial breakout in the septal groove, the ensuing activation spreads posteriorly toward the LV, favoring the left ventricle. The successful ablation site here was in the anterolateral LVOT. CRA = cranial; ECM = electrocardiographic mapping; LAD = left anterior descending; LAO = left anterior oblique; LV = left ventricle; LVOT = left ventricular outflow tract; PVC = premature ventricular complex; OT = outflow tract; RV = right ventricle; RVOT = right ventricular outflow tract.