Electrocardiographic left ventricular scar burden predicts clinical outcomes following infarct-related ventricular tachycardia ablation

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BACKGROUND Conducting channels within scars form the substrate for infarct-related ventricular tachycardia (VT) and are targeted during catheter ablation. Whether the amount of left ventricular scar (LVS) affects outcomes after VT ablation is not known.

OBJECTIVE To test the hypothesis that increased LVS is associated with worsened clinical outcomes and reduced survival after VT ablation.

METHODS Patients with coronary artery disease and intrinsic AV nodal conduction undergoing infarct-related VT ablation were studied. A validated 32-point scoring system was used to measure LVS from 12-lead ECGs. Primary endpoint was all-cause mortality or transplantation. Secondary endpoint was a composite of death, transplantation, or readmission due to VT recurrence within 1 year of discharge.

RESULTS Of 356 patients undergoing 466 infarct-related VT ablations screened, 192 (84% male, age 66 ± 11 years, 52% prior coronary artery bypass graft, ejection fraction 28% ± 11%) who underwent 245 procedures for VT (2.4 ± 1.5 VTs per patient, 31% with VT storm, refractory to 2.7 ± 1.2 antiarrhythmic drugs) between 1999 and 2009 were included. During mapping, all patients had low-voltage areas. Mean LVS was 21.4% ± 15.0%. Over 3.4 ± 3.1 years, 78 patients (41%) reached the primary endpoint (73 deaths, 5 transplants). In the first year after discharge, the secondary endpoint was reached in 56 subjects (29%). In a multivariate model, larger LVS (hazard ratio [HR] 1.03 for every 3% increase in LVS, $P < .01$), renal dysfunction (HR 2.66, $P < .01$), and increased age (HR 1.05 per year, $P < .01$) predicted mortality, whereas noninducibility of any VT was protective. (HR 0.36, $P < .01$) Larger LVS and renal dysfunction were associated with worsened 1-year outcomes, whereas noninducibility was protective.

CONCLUSION LVS burden derived from 12-lead ECGs is a significant and independent predictor of mortality and clinical outcomes in subjects with infarct-related VT.

KEYWORDS Electrocardiography; Ventricular tachycardia; Ablation; Outcomes; Myocardial infarction

ABBREVIATIONS **CMR** = cardiac magnetic resonance imaging; **ECG** = electrocardiogram; **HR** = hazard ratio; **ICD** = implantable cardioverter-defibrillator; **LV** = left ventricle; **LVS** = left ventricular scar; **VT** = ventricular tachycardia

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Introduction

Heterogeneous conducting channels within myocardial scar provide the substrate for reentrant ventricular arrhythmias and are targeted during catheter ablation of ventricular tachycardias (VT).[1] Whether a larger scar burden influences clinical outcomes after VT ablation is unknown. The gold standard for myocardial scar imaging is delayed gadolinium-enhanced cardiac magnetic resonance imaging (CMR).[2] CMR-defined scar burden predicts inducibility of VT during electrophysiologic studies and occurrence of spontaneous VT in patients with ischemic cardiomyopathy awaiting implantable cardioverter-defibrillator (ICD) implantation.[3–5] Infarct size, characterized by CMR, also is predictive of mortality in a wider population of patients with both proven and subclinical coronary artery disease.[6,7] However, in clinical practice, the majority of patients presenting with postinfarct VT have ICDs in situ and cannot routinely undergo CMR at most centers. Furthermore, CMR is costly and may not be readily accessible. In contrast, left ventricular scar (LVS) can be easily quantified and localized from 12-lead electrocardiograms (ECGs) by applying a validated 32-point QRS scoring system.[8–11] Therefore, this study was designed to test the hypothesis that LVS burden derived from 12-lead ECGs of patients with ischemic cardiomyopathy presenting with recurrent VT is predictive of adverse short-term outcomes and reduced survival after VT ablation.

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Methods

Patient selection

From November 1999 to December 2009, consecutive patients undergoing postinfarct VT ablations at our institution were screened. Inclusion criteria were documented sustained monomorphic VT, coronary artery disease, and intrinsic AV nodal conduction. Patients were excluded if they were persistently receiving ventricular pacing. In all patients, at least 1 episode of sustained VT was recorded during ECG monitoring or by an implanted ICD. Written informed consent was obtained from all patients. Procedures and review of medical records were conducted under protocols approved by the institutional review committee.

ECG assessment of LVS

Digital 12-lead ECGs of all patients up to 2 days before VT ablation were retrieved from a comprehensive ECG database (Muse, GE Healthcare, Little Chalfont, Buckinghamshire, UK) The technique of quantifying LVS from 12-lead ECGs was developed in the 1960s and further refined by Selvester et al.[8–11] This tool has been validated initially by postmortem analysis and more recently in patients with ischemic cardiomyopathy undergoing CMR.[9,10] Briefly, ECGs were classified by the presence of left ventricular (LV) hypertrophy, and presence and type of conduction defect: left bundle branch block, left anterior fascicular block, right bundle branch block, or right bundle branch block and left anterior fascicular block.[12] The QRS scoring template for the appropriate conduction defect or hypertrophy was age and sex adjusted before being applied. LVS was determined from the algorithm by measuring Q- ,R-, S-wave amplitudes, durations, amplitude ratios, and notches in 10 of the 12 leads (leads III and aVR are not used in the algorithm). Each point out of a maximum 32 awarded equates to 3% LVS. Apart from patients with left bundle branch block, the distribution of LVS could also be assigned to 1 of 12 anatomic LV segments, which in turn are arbitrarily assigned to be supplied by the left anterior descending, circumflex, or right coronary arteries. A single investigator (PK) analyzed all ECGs using a standardized protocol. In addition, 75 ECGs were randomly chosen and were reanalyzed by 2 additional investigators (MB, MT) who were blinded to the clinical data and reanalyzed in a blinded manner by PK 6 months later. In this study, manual analysis of each raw ECG required approximately 15 minutes.

VT ablation

The methods used for mapping and ablation were previously reported.[13–16] Electrophysiologic study was performed with patients in a postabsorptive state with all antiarrhythmics except amiodarone stopped for more than 5 half-lives unless incessant VT was present. Oral anticoagulants were discontinued or transitioned to heparin, which was then discontinued 6 hours prior to arrival in the electrophysiology laboratory. After venous access was attained from both femoral veins, standard quadripolar catheters were positioned to record electrograms at the right ventricular apex and His bundle. Femoral arterial access was obtained. The LV was accessed by a retrograde aortic or transatrial septal approach. Induction of VT was achieved by programmed stimulation of the right ventricular apex, using a combination of extrastimuli or burst pacing, both with and without pharmacologic adjuncts such as isoproterenol or epinephrine. Intravenous heparin boluses were administered to achieve an activated clotting time between 250 and 350 seconds throughout the procedure.

Ablation was performed with 7Fr or 8Fr steerable catheters that were either irrigated (externally and internally) or solid tipped (8 mm). Bipolar electrograms were recorded on the CARTO electroanatomic (filtered at 10 to 400 Hz) (Biosense Webster Inc, Diamond Bar, CA) or NavX (St. Jude Medical, St Paul, MN) mapping system and a separate digital system (filtered at 30 to 500 Hz; Prucka Engineering Inc, Little Chalfont, Buckinghamshire, UK). Pace-mapping, entrainment mapping, and establishing electrical unexcitability following delivery of radiofrequency energy used unipolar pacing from the distal electrode of the mapping catheter with an initial current strength of 10 mA and pulse width of 2 ms.

If VT was not incessant, the ventricle of interest was mapped during sinus or paced rhythm to identify areas with abnormal electrograms and low-voltage regions (<1.5 mV) consistent with scar. If abnormal areas were present, the mapping catheter was placed at an abnormal site that had pace-mapping characteristics of an exit or potential isthmus site, and VT was initiated to assess electrograms, perform entrainment mapping, and potentially deliver radiofrequency current to assess for VT termination. If VT was stable, was hemodynamically tolerated. and did not terminate with ablation, mapping continued during VT. If the circuit could not be identified or multiple morphologies of hemodynamically unstable VT were induced, ablation was performed through the presumptive exit and potential isthmus sites, based on voltage and pace-mapping (substrate-guided ablation).[15] Ablation lesions were created with radiofrequency current with a maximum power of 50 watts (EP Technologies, Boston Scientific, Natick, MA; or Stockert, Biosense Webster, Diamond Bar, CA) All monomorphic VTs were targeted for ablation. The desired electrophysiologic endpoint of the procedure was noninducibility of any VT or ablation performed at all target regions identifiable.

Of the 29 patients with prior failed endocardial ablation, epicardial mapping and ablation were performed with the percutaneous method (21 patients) or surgical subxiphoid pericardial window (3 patients).[17,18] Five patients required transcoronary ethanol ablation.[19]

Definitions and study endpoints

The primary endpoint was defined as a composite of all-cause mortality or cardiac transplantation. The secondary endpoint was defined as a composite of death, cardiac transplantation, or readmission due to VT recurrence within 1 year of discharge. VT storm was defined as more than 3 separate VT episodes in a 24-hour period prior to ablation. Renal dysfunction was defined as a serum creatinine level >1.5 mg/dL (133 μmol/L).