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Characterization of the Effects of Single Ventricular Extrastimuli on Endocardial Activation in Human Infarct-Related Ventricular Tachycardia

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Objectives The purpose of this study was to examine the resetting response in human ventricular tachycardia (VT) circuits with 3-dimensional mapping.

Background In characterizing re-entry with the resetting response, inferences are made about interaction of single ventricular extrastimuli (SVE) with VT.

Methods Non-contact mapping was used to examine the effects of SVE from 25 sites on 10 infarct-related VT circuits.

Results The local temporal excitable gap (EGap) was 113.8 ± 64.3 ms, 25.8 ± 11.2% of VT cycle length. In 7 VT circuits there was a clear difference in the EGap at different points in the circuit. All circuits could be pre-excited over a range of SVEs, resulting in either: 1) premature activation throughout the circuit resulting in reset; 2) premature activation at entry, but subsequent interval dependent conduction slowing (IDCS) resulting in a fully compensatory return cycle; or 3) change to functional lines of block and return cycle QRS morphology. The principal determinant of whether SVE resulted in reset was the degree of IDCS within the diastolic pathway (DP) of the circuit. Resetting occurred from 9 sites (7 VT) but was absent from 15 sites despite pre-excitation of a sizeable EGap in the circuit in all cases.

Conclusions In infarct-related VT, all circuits can be pre-excited over a range of SVEs, the effect of which is dependent on the degree of IDCS within the DP or modification of functional block defining the circuit. Failure to reset does not therefore indicate the absence of an EGap or failure of entry to the circuit. The temporal and spatial properties of the EGap vary at different sites of entry to the circuit. (J Am Coll Cardiol 2007;49:1315–23) © 2007 by the American College of Cardiology Foundation

The resetting response, the use of premature stimuli to advance a re-entrant tachycardia, has been used to examine the properties of the excitable gap (EGap) in circuits causing ventricular tachycardia (VT) in both animal models and human studies (1–6). Almendral et al. (7) identified 3 patterns of resetting response in re-entrant human VT circuits: flat (due to full excitability of the EGap), increasing (partial excitability), and mixed (initially fully excitable then partially excitable with shorter coupling intervals [CIs]). However, these inferences were based only on the surface electrocardiogram (ECG) and electrograms at the site of pacing and 1 other site and on the premise of fixed, anatomically constrained re-entrant circuits. We and others have shown that lines of block that define human infarct-related VT circuits have functional characteristics (8–11) and what is not known is the mechanism by which extrastimulated wavefronts interact with native VT circuits, what effects this has on lines of block, and how these manifest in response to extrastimuli and the surface ECG. Understanding these interactions will help characterize and classify circuits causing VT in the quest to develop more specific strategies for ablation, anti-tachycardia pacing, and drug therapies.

We have previously examined the interaction between extrastimuli and functional components of VT circuits and properties of the EGap in the well characterized canine infarct model with epicardial isochronal mapping (3,12). We demonstrated that temporal and spatial qualities of the EGap vary at different points within the circuit (12). In the present study, we have used non-contact mapping to characterize the interaction of premature extrastimuli in human,

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Abbreviations and Acronyms

CI = coupling interval
CL = cycle length
DP = diastolic pathway
ECG = electrocardiogram
EGap = excitable gap
IDCS = interval dependent conduction slowing
LV = left ventricle
SVE = single ventricular extrastimuli
VT = ventricular tachycardia

infarct-related VT circuits in order to address the hypotheses that because lines of block defining such circuits have significant functional components, temporal properties of the EGap vary at different sites of entry within these circuits and changes to lines of block and conduction properties within re-entrant circuits underlie the different effects seen with extrastimuli.

Methods

Patients. A total of 9 patients (62.7 ± 5.1 years, 1 female), all undergoing ablation of VT, were studied with the non-contact mapping system (EnSite 3000, Endocardial Solutions Inc., St. Paul, Minnesota). All had poor left ventricular (LV) function (ejection fraction 32.9 ± 6.3%) and previous, remote (>6 months) myocardial infarction (4 anterior, 3 inferior, and 2 both anterior and inferior). Five patients were taking amiodarone, 2 patients amiodarone and mexilitene, 1 patient sotalol, and 1 patient was intolerant of antiarrhythmic medication. Local ethics committee approval was obtained, and patients had given written informed consent.

Mapping. Non-contact mapping of VT has been described in detail before (13). In brief, a 9-F 64-wire balloon mounted multi-electrode array was deployed in the LV retrogradely, a 3-dimensional LV geometry created, and high resolution isopotential maps recorded. A standard quadripolar catheter was positioned at the right ventricular apex, and 2 7-F mapping/ablation catheters were deployed into the LV, with a retrograde and trans-septal approach. The ECG and contact catheter data were recorded on a conventional electrophysiological system. Ventricular tachycardia induction was attempted by programmed stimulation with the Wellens protocol (14).

Resetting protocol. Pacing was attempted from both LV catheters and the right ventricular apex (RVA) catheter. The single ventricular extrastimuli (SVE) were delivered during VT starting at the VT cycle length (CL) and then 10-ms decrements until loss of local capture (refractoriness), change in VT morphology, or termination of VT occurred. If local capture was not obtained at any interval when pacing in the LV, resetting was attempted from an alternative site. Resetting was attempted from at least 3 sites (right ventricular and 2 LV positions) if the tachycardia remained hemodynamically stable. Data analysis was performed off-line after the procedure.

Calculation of the EGap. For the purposes of calculating the properties of the EGap, reconstructed electrograms were selected from the outer (systolic) portion of the circuit, parallel and adjacent to the line of block defining the diastolic pathway (Fig. 1A). Activation times were defined as the maximum negative slope (dV/dt) of unipolar electrograms, and local CLs of the native cycle, the paced cycle, and the return cycle were measured at each site. An example is shown in Figure 2. Accuracy of this measurement was confirmed by examining the morphology and intervals of reconstructed bipolar electrograms at the same sites (with a function of the Endocardial Solutions Inc. software) and by analysis of activation

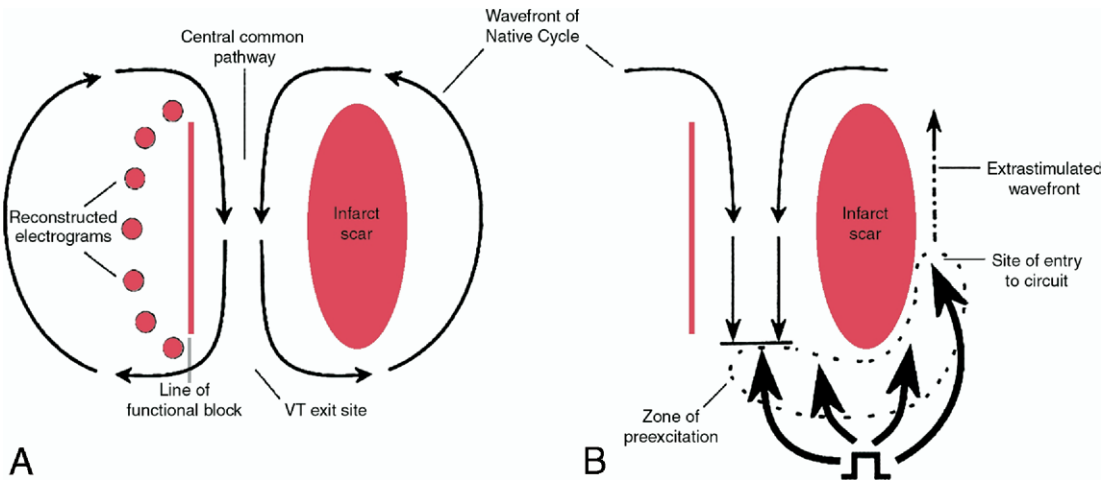

Figure 1 VT Circuit Depiction, Placement of Reconstructed Electrograms, and Resetting Definitions

(A) Schematic representation of an infarct-related ventricular tachycardia (VT) circuit with the central common pathway bordered by presumed scar and a line of functional block. A figure-8 re-entrant native cycle is shown. Reconstructed electrograms were placed parallel and adjacent to this line of block to calculate the local temporal excitable gap within the circuit. **(B)** A single ventricular extrastimulus arising from the site of stimulation (pacing symbol) preexcites the circuit leading to an extrastimulated wavefront. Collision with the native cycle wavefront in the DP is shown. See text for discussion. DP = diastolic pathway.