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EDITORIAL COMMENT

New Parameter for Detecting Isthmus Location in Ventricular Tachycardia Caused by a Re-Entrant Circuit*

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A new parameter has been developed for the identification of the isthmus of the re-entrant circuit causing ventricular tachycardia. The parameter, termed simultaneous amplitude frequency electrogram transformation (SAFE-T), works by determining the instantaneous frequency and the instantaneous amplitude of the electrogram, using a specialized version of the Hilbert-Huang transform. When the instantaneous frequency of the electrogram is high, and the amplitude of the electrogram at that instantaneous time epoch is substantial, it results in a large value of SAFE-T, and is indicative of the presence of an arrhythmogenic potential. The electrogram content in these instances is likely reflective of very complex fractionation, which requires very high frequencies to reproduce the signal, and therefore consists of very complex electrical activation patterns. Based upon previous work, such regions may coincide with the isthmus lateral boundaries, where wavefront discontinuities are likely to occur (1). By ablating across such regions, it is possible to interrupt the reentrant circuit and prevent reinduction of ventricular tachycardia. Because the electrograms can be acquired for SAFE-T during multiple rhythm types including normal sinus rhythm, extra ventricular beats, and right ventricular pacing, it is convenient to use during electrophysiological study for catheter ablation of ventricular tachycardia.

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DESCRIPTION OF THE STUDY

Ablation of re-entrant circuits to prevent reinduction of ventricular tachycardia is an important clinical problem. It is sometimes difficult to localize the optimal sites that when ablated will interrupt the circuit and prevent reinduction of any and all clinical reentrant ventricular tachycardias. The problem is complicated by the fact that when multiple reentrant ventricular tachycardia morphologies are inducible, the isthmus of each may not necessarily overlap (2,3). In this issue of *JACC: Clinical Electrophysiology*, a study is presented entitled "Simultaneous Amplitude Frequency Electrogram Transformation (SAFE-T) Mapping to Identify Ventricular Tachycardia Arrhythmogenic Potentials in Sinus Rhythm" (4). In this investigation, the authors have developed a time-frequency parameter to detect arrhythmogenic potentials that colocate with the isthmuses of reentrant circuits causing ventricular tachycardia. By ablating at sites with arrhythmogenic potentials, the electrical activation circuit causing ventricular tachycardia can be more efficiently and efficaciously interrupted.

The parameter developed by this group of investigators is based upon the measurement of surface electrograms acquired from the distal bipolar ablation catheter electrode. The advantage of this type of method is that the derived instantaneous frequency is associated with a single instance in time, rather than with a long duration signal as is the case when the Fourier transform is implemented. Thus, a timely assessment of the frequency content of the recorded electrogram is achieved. The actual SAFE-T parameter is the product of the instantaneous frequency and the amplitude of the bipolar electrogram at that same instant of time, after a filter is applied. Values of

SAFE-T above a threshold, as developed by the authors, are indicative of the presence of an arrhythmogenic potential. Thus, when both electrogram instantaneous frequency and amplitude are of relatively greater magnitude, the electrogram acquisition site is likely to be located in an area of arrhythmogenicity, and specifically, at the isthmus of the reentrant circuit that is driving the ventricular tachycardia. The isthmus is the common region between a double-loop reentrant circuit. Application of radiofrequency catheter ablation energy to interrupt the circuit at this location will prevent reinduction of the tachycardia morphology because the pathway of the electrical impulse is constrained there by functional conduction block at the lateral boundaries (1). The SAFE-T parameter was found in the study to be extractable from electrograms acquired during normal sinus rhythm, extra ventricular beats, and right ventricular pacing. Thus, it has the utility to be used in multiple rhythm types, and is potentially useful during ventricular tachycardia as well.

Two SAFE-T thresholds were determined in the study to quantify the electrograms—a value <3.08 Hz-mV was used to indicate a relatively normal electrogram, a value of 3.08 Hz-mV < SAFE-T < 4.89 Hz-mV indicated an abnormal electrogram, and a SAFE-T value >4.89 Hz-mV was indicative of a highly abnormal electrogram. The authors found that at nonisthmus areas, the electrogram SAFE-T value averaged 2.0 ± 3.0 Hz-mV, whereas at isthmus locations SAFE-T averaged 6.6 ± 2.9 Hz-mV ($p < 0.01$). Thus, at isthmus locations, the instantaneous frequency tended to be higher, and was associated with a significant electrogram amplitude level. Figures 6 and 7 in the article by Lin et al. (3) show substantial overlap of high SAFE-T areas with isthmus locations. In Figure 6, maps are shown for a patient with multiple reentrant ventricular tachycardia morphologies. The isthmuses share a common center, similar to what has been observed in canine studies by our group (2,3). Ablating any single isthmus would fail to interrupt all 3 possible clinical re-entrant ventricular tachycardias for the patient data of Figure 6. Thus, the SAFE-T map is helpful to visualize the best place to ablate, which would be at the junction of the three isthmuses.

PERSPECTIVE

The method developed by the investigators appears to work because relatively high instantaneous frequencies would be expected to be associated with very complex fractionated electrograms. These highly complex fractionated electrograms tend to cluster at isthmus locations in the study. By comparison, in post-infarction canine left ventricle, the reentry isthmus lateral boundaries are associated with highly complex fractionated electrograms caused by wavefront discontinuities (5). Thus, areas in proximity to the isthmus lateral boundaries, both within and outside the isthmus, would also be expected to exhibit increases in SAFE-T in the canine model. Molecular mechanisms may also play a role in producing wavefront discontinuities at lateral isthmus boundaries (6). The presence of fractionation in and around the isthmus locations at the lateral boundaries could in part account for the presence of some high SAFE-T regions outside of isthmus boundaries found in the study. Overall, the study is of potential importance to better localize the reentrant ventricular tachycardia isthmus and to interrupt the electrical activation circuit during catheter ablation.

During ventricular tachycardia, wavefront direction may change as compared to the normal sinus rhythm (5). In canine studies, electrogram fractionation is still evident at the same regions during ventricular tachycardia as compared with sinus rhythm, although not necessarily at all of the same sites. However, the morphology of electrogram fractionation differs in ventricular tachycardia versus sinus rhythm (5). During ventricular tachycardia, fractionation averages 7.6 ± 1.2 deflections and 16.3 ± 8.9-ms intervals per cardiac cycle. During sinus rhythm, fractionation averages 5.9 ± 1.8 deflections and 9.2 ± 4.4-ms intervals per cardiac cycle. The shorter intervals between deflections during sinus rhythm would likely lead to higher instantaneous frequencies, thus making arrhythmogenic potentials more readily detectable during this rhythm. The longer interval between deflections during ventricular tachycardia may decrease the instantaneous frequency, possibly causing slightly more difficulty in identifying arrhythmogenic potentials with SAFE-T during this rhythm.

A possible advantage of SAFE-T over current conventional methods is that it is not necessary to map the entire isthmus to determine optimal ablation sites. Because any recording site with arrhythmogenic potentials as measured by SAFE-T is likely to be within the re-entry isthmus, ablating there and then moving on is probably a good strategy, rather than having to come back to the same spot to ablate later. Only when it is suspected that multiple re-entry morphologies share a common isthmus would it be prudent to map the entire region before ablating to find the common area of all the isthmuses. Although the SAFE-T and fractionation measurements were acquired from surface re-entrant circuits, it is probable that similar mechanisms causing functional

block drive intramural re-entrant circuits (7). Therefore, it would be possible to also identify any isthmus present in the midmyocardium using SAFE-T, supposing that a suitable technique were available to acquire fractionated electrogram recordings from these regions.

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